A LABORATORY MANUAL OF HIGH SCHOOL BOTANY

CLEMENTS
CUTTER

A LABORATORY MANUAL

OF

HIGH SCHOOL BOTANY

BY

FREDERIC E. CLEMENTS, PH.D.,
Instructor in Botany in the University of Nebraska,

AND

IRVING S. CUTTER, B.SC.
Principal of the Beatrice High School.

LINCOLN, NEBRASKA.
THE UNIVERSITY PUBLISHING CO.
1900.

JACOB NORTH & CO., PRINTERS
LINCOLN, NEB.

PREFACE

THE present work is intended solely as a laboratory guide in connection with lectures or a text-book. The matter has, in consequence, been presented in the briefest and most compact form consistent with this purpose. The aim is to put the student to work quickly and to keep him at work intelligently. Explanation has been added only when it seemed essential to the proper handling of the laboratory work. The material and the teacher have been regarded as the two important facts in the work. The laboratory directions, it is hoped, will bring the student into direct contact with the material, and will relieve the teacher of a large amount of drudgery, thus giving him time for real teaching.

The Manual is an authoritative expression from the Department of Botany of the University of Nebraska upon the kind and amount of elementary botany that should be taught in the accredited schools and colleges of the state. It has been written with the idea of making it possible for schools to give at the same time the proper preparation in botany to those intending to go to college, and a broad and scientific view of plants to those who stop at the end of the high school. In consequence, it can not be used in part, if the best results are desired. The completion of the entire work as outlined gives two credit points. In those schools which are not yet prepared to give the subject the full amount of time, a credit of one point will be given for a prescribed amount of work done in the different divisions. The amount of work required for one credit point may be learned by communicating with the Department of Botany.

University of Nebraska, August 1, 1900.

CONTENTS

GENERAL DIRECTIONS

THE LABORATORY

The laboratory should, wherever possible, be used solely for this purpose. When the class is not too large, the laboratory might be used also as a botanical lecture room. The laboratory windows should be high and wide, and should face the north or the east. West windows are serviceable only in the morning, while south windows are never satisfactory. The room should be furnished with regular microscope tables, having heavy tops and broad, solid supports, placed next the windows. Low deal tables may, of course, be used in their stead if absolutely necessary. The room should contain, also, a microscope case, material case, shelves for books, a set of lockers, a sink, and several slop jars. A good blackboard as well as a convenient place for hanging charts are essentials.

THE MICROSCOPE

The microscopes should be selected for compactness and serviceability. They should be furnished with two objectives and two eye-pieces, one containing a micrometer. If the microscopes are fitted with double nose-pieces, a great saving of time will result, and the objectives will wear longer. In buying microscopes, it is much better to buy several simple, medium-priced instruments that will do all that is required of them than to buy one or two high-priced microscopes which are altogether out of place in an elementary laboratory. The following microscopes are recommended by the Department of Botany for use in the high schools and colleges. Bausch & Lomb OA microscope with two oculars, one containing a micrometer, $^1/_3$, $^1/_6$ objectives and double nose-piece, costing approximately $23. Leitz, Stand IV, with No. 2 and 3 ocular, No. 3 and 7 objectives, and double nose-piece, $22.50. The latter may be obtained of William Kraft, 411 West 59th St., New York. In the case of high schools, it is preferable to buy from Bausch & Lomb, simply for the reason that it is not necessary to wait for importation, as is the case with the Leitz instruments. There is practically no difference between the two makes of instruments.

LABORATORY EQUIPMENT

Each laboratory table should be supplied with a set of drop bottles containing the following reagents: alcohol, glycerin, iodin, potassium hydrate, sulphuric acid conc., anilin sulphate, safranin, gentian violet, methyl green, hydrochloric acid. Probably all of these may be obtained from the local druggist, with the exception of the last four which may be bought of Bausch & Lomb. The salts used in making experiments with nutrient solutions should be obtained from this company also.

Satisfactory laboratory work is impossible without good tools. For this reason it is unwise to use odds and ends in the way of razors, scalpels, tweezers, etc.

No work should be attempted without good dissecting sets, each set being assigned to as few students as possible. At the end of each working period, the teacher should see that the set is returned in perfect condition. A good hone and strop should be provided, and the students thoroughly instructed in their use and care. The botanical dissecting sets, yellow Belgian hones, and good strops may be obtained of Bausch & Lomb.

Bessey's "Essentials of Botany," 7th ed., and Pound and Clements' "Phytogeography of Nebraska," 2d ed., should be constantly at hand as reference books or as texts. In addition, every botanical laboratory should have a copy of each of the following:

MacDougal's "Experimental Plant Physiology," $1.

Sachs' "Text-book of Botany," The MacMillan Company, 66 Fifth Av., New York, $5.

Strasburger's "Text-book of Botany," The MacMillan Company, $4.50.

Bennett and Murray's "Cryptogamic Botany," Longmans, Green and Co., 15 E. 16th St., New York, $4.15.

Britton and Brown's "Illustrated Flora of the Northern United States," Charles Scribner's Sons, New York, 3 vols., $9.

Zimmermann's "Botanical Microtechnique," Henry Holt & Co., New York, $2.60.

"Flora of Nebraska," Parts I and II. Botanical Seminar, University of Nebraska, Lincoln, $2.

Webber's "Catalogue of the Plants of Nebraska" may be obtained from the Department of Botany for twenty-five cents.

Bessey's "Synopsis of the Vegetable Kingdom," a wall chart, may be obtained for fifteen cents.

CARE OF LABORATORY EQUIPMENT

The greatest care should be insisted upon in the use of the microscopes. The latter should be kept in a tight case as free from dust as possible. The student should be taught to clean the outer lenses of both eye-pieces and objectives with lens paper when the instrument is taken out and put away. The lens paper should be clean and must be kept in a dust-free place, such as between the sheets in the back part of the student's laboratory notebook. If the microscopes are new or only slightly used, the student should be required to clean the stand thoroughly with chamois skin or a linen cloth before returning it to the case. If the double nose-piece is used, the student must be taught always to find the object under the low power objective and then to swing the high power into position carefully. Without the nose-piece, the high power should never be twisted down upon the object while the eye is applied to the eye-piece. The objective should be lowered slowly until only a thin line of light remains between the front lens and the top of the cover glass, when it should be raised slowly until the object is seen in the field. In making tests with acids and alkalies, the work must always be done under the eye of the teacher and, as a rule, with the low power. Under no circumstances should any of the acid or alkali be outside the cover glass. It must be insisted on as an absolute rule that neither eye-piece nor objective be taken apart by any one except the one in charge of the laboratory.

The glassware essential for microscopical work is slides, covers, and watch-glasses. In addition, there should be drop bottles for reagents and Petri dishes for materials. Water dishes of glass or stoneware should be kept on the tables. The laboratory should have at least one graduate ruled in cubic centimeters. A slide micrometer is necessary for exact microscopical measurements. Large battery jars should be obtained for aquarium purposes. For physiological work, there should be a supply of bell-glasses, beakers, flasks, bottles, test-tubes, cylinders, glass tubing and rubber tubing, the amount depending upon the size of the class. These supplies can be obtained of the Bausch & Lomb Company, Stewart Building, Chicago.

BOTANICAL MATERIAL

The materials necessary for laboratory work should be collected by the teacher as far as possible. Whereever possible, as much material as is needed should be collected during the spring and summer and preserved in the proper fluid. Ordinary histological material may be put directly into 30 per cent alcohol when collected, and trasferred a few days later to 60 per cent alcohol in which it will keep indefinitely. Algae, delicate tissues, etc., should first be killed in Flemming's, the first for 10 to 30 minutes, the second for 1 to 3 hours. Algae are best preserved in a 1 per cent water solution of chrom alum, a few drops of formalin being added to each 100 cc. It is most satisfactory to keep algae constantly growing in aquaria, if the latter can be kept from freezing. If the water in the aquaria is aerated every day by allowing fresh water to fall into it from a height of two or three feet, the algae will remain growing for a long time. Wherever a greenhouse is readily accessible, fresh material should be used except in the rare cases where preserved material cuts more readily or shows some point not evident in fresh specimens. The greenhouse, if kept at all moist, will furnish an unfailing supply of Protophytes, in addition to the histological material. Cup fungi, mushrooms, mosses, liverworts, ferns, and horsetails may be readily grown in the greenhouse as well. In case it is impossible to get material for any reason, a complete supply of the materials required in the present Manual will be kept by the Department of Botany. These will be supplied to schools at the actual cost of collection and of preservation. In sending an order for material, indicate the plants desired and the number of students in the class. Address the Department of Botany, University of Nebraska, Lincoln, writing "Supplies" in the lower left hand corner.

PREPARED SLIDES

Prepared slides should never be used in the regular work under any condition. The student should be taught to make his own slides, the chief value of laboratory training being in the self-reliance which it develops. Demonstration slides may occasionally be used in connection with the text or lectures, but only in the case of those objects which it is impossible for the student to prepare for himself. In consequence, teachers are strongly urged not to use prepared slides for any of the regular work of the Manual. Slides showing karyokinesis, etc., for the purpose of demonstration, will be furnished by the Department to schools at cost.

SUGGESTIONS REGARDING THE COURSE

In the disposition of the time which is given to botany, it is recommended that the class-room work be reduced to a minimum. If five hours are given each week, only one or two should be used in the class-room, and the remainder in laboratory work. A single lecture a week, in connection with the texts and readings, will enable the student to follow the laboratory work to the best advantage. The need of recitations may be obviated by frequent quizzes, either in the laboratory or class-room. The really important part of all scientific teaching is actual contact with the things studied, and, in conformity to this, everything else in the course should be subordinated to the laboratory. If the teacher or an assistant is constantly in charge of the laboratory, the lectures should touch upon different parts of the subject after the student has worked over them, completing and connecting the facts he has seen for himself in the laboratory. If the student must work alone part of the time, he will usually work to better advantage if he has the lecture notes as an aid. When the amount of time given to botany is only sufficient for the laboratory work, the best plan will be to use the "Essentials of Botany" and the "Phytogeography of Nebraska" as text-books, following the references to them given in the laboratory manual.

At the beginning of the work, the student must be taught how to set up, use, and take care of the microscope, and how to make measurements with the micrometer. He must have impressed upon him the need of taking the best care of the instrument, especially the eye-pieces and objectives. He must learn to focus quickly and to find objects in the field at once. He should never be permitted to begin work until he uses the microscope readily, or he will always be handicapped by this inability. Fairly accurate measurements of an object may be made by keeping both eyes open when looking through the eye-piece, so that the object may be superimposed upon a pencil held in the hand in such a way that its length or width may be measured. A much more accurate and satisfactory way is by means of an eye-piece micrometer, a small scale usually fastened in the eye-piece. The value of one space of this scale is sometimes given by the maker of the instrument. If such is not the case, it must be determined by the use of a stage micrometer, a slide with one or two millimeters ruled in tens, and one of the latter ruled in ten smaller spaces. The value of a millimeter being 1,000 micromillimeters, the unit of microscopical measurement, usually designated by the Greek letter mu, μ, the larger spaces of the stage micrometer will contain 100 micromillimeters or μ, and the smaller, 10 μ.

To find the value of a space of the eye-piece micrometer, determine the number of spaces eye-piece micrometer in a certain number of spaces stage micrometer, reduce the latter to μ, and divide by the spaces of the eye-piece micrometer. If 6 spaces of the eye-piece micrometer equal 1 space of the stage micrometer, then x, the space of the eye-piece micrometer, equals 1 multiplied by 100μ, divided by 6.

$$x = \frac{1 \times 100}{6} = 16.6\mu$$

The value of the eye-piece scale is found in the same way for both high and low power objectives.

The number of diameters of magnification of the high or low power may be found by projecting, with both eyes open, the eye-piece scale upon a millimeter rule placed upon the table alongside the microscope, and by determining the ratio between the two. The ratio between the eye-piece micrometer and the millimeter rule being determined, to find the magnification of high or low power, reduce the spaces of eye-piece micrometer and of millimeter rule to μ and divide the latter by the former. If 5 spaces of the eye-piece equal 6 of the rule, then y, the number of magnifications, will equal 72.

$$y = \frac{6 \times 10{,}000}{5 \times 16.6} = 72 \text{ diameters.}$$

In order to draw accurately, it is necessary to know the magnified size of the object in millimeters. The magnified size is found by reducing the number of spaces of eye-piece micrometer to μ, multiplying the result by the magnifying power, and dividing by 1,000 in order to reduce to millimeters.

$$z = \frac{10 \times 16.6 \times 72}{1000} = 11.9 \, mm.$$

If each student is required to make out a table such as the following, and to keep it in his laboratory note-book, much time will be saved in working out the value of measurements.

	ACTUAL VALUE		MAGNIFIED VALUE
SPACES	2–3	2–7	2–3 AND 2–7
1	16.6 μ	2.7 μ	1.29 *mm.*
2	33.2 "	5.4 "	2.58 "
3	49.8 "	8.1 "	3.88 "
4	66.4 "	10.8 "	5.17 "
5	83.0 "	13.5 "	6.47 "
6	99.6 "	16.2 "	7.76 "
7	116.2 "	18.9 "	9.06 "
8	132.8 "	21.6 "	10.35 "
9	149.4 "	24.3 "	11.65 "
10	166.0 "	27.0 "	12.94 "

If the object measures between one and ten spaces, its actual and magnified size will be found at once. Above ten, the number of spaces may be factored at a glance and the factor referred to the table.

The best method of work is first to examine the object in the gross, then under the low power, and finally under the high power. As the results of the observation, the notes, are written up, the measurements should be made and recorded. In all cases, the student should be encouraged to write up his notes without the questions and suggestions given after each experiment. He should be taught to observe and think for himself, though at first suggestion will be found absolutely necessary. The drawing should never be begun until the student has made all the observations required. Having found the dimensions of the magnified object by reference to the table, the exact size may be measured upon the drawing paper and the student is ready to begin his drawing. In schools where no adequate instruction in drawing is given, the student should be instructed in making straight lines and curves with a sweeping stroke, and in fine stippling. A poor line or an incorrect one should be erased at once: a second line should never be drawn until the first one is out of the way. The drawing sheet should be loose in order that it may be turned readily in any direction. This is necessary since a sweeping stroke is more easily acquired if the line is always drawn in the same direction. The teacher should supervise, in so far as possible, the making of the first drawings so that the student may not lose any time in having to redraw a completed drawing. After a time the student may be trusted more and more in making independent drawings, always with the understanding that a poor or careless drawing must be redrawn. In those schools in which botany is taught for the maximum time throughout the year, ink drawings may be made with good results, but in most schools the extra time demanded by the inking makes it out of the question. The ink used is Higgins' Waterproof Black Ink. It may be used undiluted, giving a black line, or it may be diluted with water fifty parts, making a gray ink, called outline gray, which is especially good for drawing tissues, outlines, etc. Outline gray flows more readily than the black ink, also. The stippling should generally be done with the black. The only good drawing pen is Gillott's Crowquill Pen, 659.

THE NOTE BOOK

The laboratory notebook should consist of a history cover $7\frac{3}{4}$x10 inches, filled with alternate sheets of drawing paper and note paper. It may be obtained of H. W. Brown Co., 127 South 11th, Lincoln, Nebraska.

The drawing page should be arranged to the left, the note page to the right. As a rule, only two drawings should be made on each page. Generally, the notes on each study will require a page so that the drawing page should be followed by two note pages. Nothing should be placed upon the page in addition to the drawings, except the necessary lettering. In the histological work, the notes may be written up without regard to any fixed arrangement, but in the study of plant forms, a definite scheme saves time and aids in making the notes more easily accessible. In the following sample note page, the classification of the plant is given first, followed by a short description of the plant, giving measurements, and then by answers to the questions suggested.

Gloeocapsa arenaria

Branch Protophyta: Gr. protos, first; phyton, plant.

Class Schizophyceae: Gr. schidzo, split; phykos, seaweed.

Order Cystiphoreae: Gr. cystis, sack; phora, bearing.

Family Chroococcaceae: Gr. chroos, color; kokkos, berry.

Genus Gloeocapsa: Gr. gloios, glue; kapsa, chest.

Species arenaria: L. arena, sand.

Plant mass mealy, light blue, 1-3 mm. long; cells globose to elliptical, slightly granular, blue green, 5-7 μ, furnished with a lamellose colorless sheath, grouped in colonies of 2-4-8.

Growing upon flower pots in the greenhouse.

The cells are all vegetative and alike, varying in shape only during fission. The cells are globose for the most part and are nearly homogeneous within, neither nucleus nor plastids being visible. Increase takes place only by fission, each cell elongating from globose to elliptical and constricting at the edge until pinched into two new cells. Compared with the ordinary cell of parenchyma, the cell is much simpler, lacking apparently nucleus, plastids, and other cell contents.

The etymologies of the names of the various groups, which will be found in the glossary, should be given each time a name is repeated, as they make the names much more serviceable, though they may be left out entirely if they are found to require too much time.

DIRECTIONS FOR CUTTING SECTIONS

The importance of keeping the razor always sharp can not be over-estimated. The time lost in vainly endeavoring to make a dull razor cut thin sections is much more than enough to keep the razor in excellent cutting condition. The teacher must see to it that razors are kept constantly sharp. The material to be sectioned must be as fresh as possible. With rare exceptions, preserved material should not be used when fresh material is available. The material, whether fresh or preserved, should be kept in cold water when in use. The specimen from which sections are to be cut should be held firmly between the thumb and forefinger, the latter a little lower, affording a support for the blade of the razor. The edge of the specimen and the razor edge should be kept wet with water in order that the razor may take hold readily. The stroke should be started about an inch from the heel of the razor and the latter should be drawn with a long sweeping motion clear through the specimen. Sections should always be cut at a single stroke, unless very large. The sections are removed from the razor and placed in a drop of water on the slide, and a clean cover is dropped over them. Care should be taken in a temporary mount to avoid bubbles, and water outside of the cover. From time to time water must be added at the edge of the cover in order to prevent drying out. The best practice in section cutting is to cut a dozen or two sections into a watch-glass of water, and then select the thinnest ones. A great deal of time is consumed in stopping to examine each section as it is cut, only to find that it is too thick. If the sections are intended for permanent mounting, in addition to being thin and complete, they must also be uniform, i. e., equally thick throughout. A common fault of sections is that the edge is turned. This is often due to a dull razor; sometimes it arises from the fact that the razor is pushed against the epidermis or bark instead of being drawn obliquely. Finally, a thick section should never be used. Thin sections are made only by practice.

PERMANENT MOUNTS

Permanent mounts of tissues are best made by removing the water by means of alcohol and mounting in balsam. Thin uniform sections are cut into a watch-glass of water. If the tissues are delicate, the sections should be started in 25 per cent alcohol and then changed successively to 45, 60, 75, and 95 per cent alcohol, remaining only a few minutes in each. They are then placed for one to two minutes in 100 per cent alcohol, cleared in bergamot oil for five or ten minutes, and mounted in balsam. A drop of thin balsam is placed in the center of the slide, the section placed in it from the bergamot, and the cover laid upon it. The cover should be started at one edge of the drop and lowered slowly to prevent air bubbles. If the latter form, the cover should be removed and a new one used. As little balsam as possible should be used. If sections of hard tissues, such as woody, stony, etc., are to be mounted, they may be started at once in 95 per cent alcohol. It is usually necessary to leave them in the latter for several minutes, or sometimes even for hours or days, in order that all air bubbles may be removed from the tissues. Such sections should be stained by placing them from 95 per cent alcohol into an alcoholic solution of some stain, preferably safranin, for five to ten minutes. They are then washed in 95 per cent alcohol until clouds of stain cease to be given off, run through 100 per cent, cleared in bergamot, and mounted. Nearly all tissues should be stained if permanent mounts are to be made of them. For woody tissues, safranin is the best; for cellulose or soft tissues, haematoxylin or methyl green. An excellent double stain may be obtained in sections containing both woody and soft tissues by staining them for ten to fifteen minutes in safranin, washing in 95 per cent, staining in dilute methyl green for ten to fifteen seconds, washing quickly in 95 per cent, running through 100 per cent, clearing in bergamot and mounting in balsam. Spores, pollen grains, etc., may also be mounted in balsam, though usually without staining. Algae and delicate parts of plants are best mounted in glycerin jelly. The algae are run through 10, 20, and 30 per cent glycerin and then placed in a drop of jelly on the slide. Glycerin jelly is solid at ordinary temperatures and must be kept warm while in use. It is well to keep both slide and cover warm also. The jelly solidifies again on cooling and the slide does not require sealing.

PERMANENT MOUNTS—PARAFFIN IMBEDDING

Paraffin imbedding and sectioning on the microtome require considerable apparatus and are inconvenient without gas burners. In consequence, they can not be carried on in many high schools. A brief outline of the method will be given here, however, for the sake of those schools where it is possible to make use of the paraffin process. The different parts of the process are known as killing, washing, dehydration, clearing, infiltration, imbedding, sectioning, and mounting. Killing stops the activity of the cells quickly and fixes the cell contents so that the subsequent processes will not change them. Washing removes the killing medium in order that it may not prevent ready staining. Dehydration substitutes alcohol for the water of the cell cavity and makes it possible to clear the specimens in bergamot oil preparatory to transferring them to paraffin. Infiltration consists in warming the sections in a mixture of bergamot and paraffin in order to make it possible to imbed them in melted paraffin without harm. The material to be imbedded should be killed in Flemming's solution, a mixture of acetic, osmic, and chromic acids, the length of time necessary depending upon the size of the specimens and the kind of tissue. The root-tips of the hyacinth are killed in 4 to 6 hours, while stems and harder tissues require 12 to 24 hours. The amount of killing solution should be at least ten times as much as the bulk of the material. Washing may be effected by leaving the specimens in slowly running or dripping water for a time equal to that in which they were killed, or by putting the specimens in a large bottle or beaker and changing the water every hour. Root-tips should be started in 10 per cent alcohol and then run every half hour or hour through grades 5 per cent apart, i. e., 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, and 100 per cent. In the case of harder tissues, the specimens should be started in 30 per cent and run through a series of alcohols 10 per cent apart, remaining in each for 1to 3 hours, depending upon the size of the specimen. When it is found necessary to interrupt the process, the material may be left without harm in the lower grades of alcohol. As a rule, material should not remain in a grade above 90 per cent over night; most tissues become hardened and brittle if left in 100 per cent for more than 8 to 10 hours, while root-tips should not be left in it for more than 3 to 4 hours at the outside.

CLEARING

In clearing, the material is placed in a mixture of equal parts of 100 per cent alcohol and bergamot oil, or part of the 100 per cent used in dehydrating may be poured off and the bergamot added directly to the remainder. With delicate tissues, root-tips, ovules, etc., the specimens are run through four grades containing respectively 20, 40, 60, and 80 per cent of bergamot, remaining 1 to 2 hours in each. The latter should clear in the bergamot over night, which is also sufficient for harder tissues unless the specimens are quite large.

INFILTRATION

Infiltration must be carried on at a temperature of 30° to 45° C. This may be done best by using a water bath, preferably number 3535 of the Bausch & Lomb catalogue. The bath must be furnished with a thermometer for reading temperatures, and a thermostat for regulating the flow of gas and maintaining the bath at a constant temperature. A piece of paraffin about equal in bulk to the bergamot is placed in the vial containing the latter, and the vial put in the bath at the temperature of the room. The burner is lighted and the thermostat so regulated that the temperature of the oven rises from the room temperature to 45° C. in 3 to 4 hours. Infiltration is continued at this temperature for 1 to 3 hours longer in the case of root tips, and for 8 to 10 hours with harder tissues. As the paraffin dissolves, more should be added until the bergamot will take up no more.

IMBEDDING

Imbedding is effected in the same bath. Halves of Petri dishes (50 mm., 3802, B. & L.) should be filled with paraffin melting at 45° C. at the time the bath reaches 45° in order that paraffin may be melted by the time the specimens are ready to be transferred from the mixture of bergamot and paraffin. In order to remove all the bergamot, it is better to transfer the specimens from bergamot-paraffin to melted paraffin for two or three hours and then to place them finally in the dish in which they are to be imbedded.

Root-tips should be imbedded altogether for 5 to 6 hours, while stems, etc., will require 12 to 24 hours. The dish should be taken from the bath at the proper time and placed on top of the latter, where the specimens may be arranged with a warm needlepoint. It is then placed close at hand with as little jarring as possible and allowed to cool until a white film forms on the top, when it is floated carefully upon the surface of a dish of cold water. As soon as the paraffin forms a thick crust, the dish is sunk and the paraffin allowed to become hard. In order to remove the paraffin block from the Petri dish, the latter is placed upside down in a dish of ice water for 2 to 4 hours, when the block will either fall out or will be easily removed by means of a scalpel. The specimens should now be cut out of the paraffin. In cutting, it is best to leave about the specimen a wide margin, which may then be trimmed close, taking care to make the faces of the block flat and parallel. A margin should be left on one side to permit of easy attachment to the stick.

Each block is then attached to a pine stick about 25 mm. long and 6 to 8 mm. square by dipping the end of the stick in the melted paraffin, placing the block squarely upon the end and building up about its base with melted paraffin taken up by a pair of tweezers. The stick with its block attached should be placed in cool water until it is ready to be sectioned.

CUTTING THE SECTION—THE MICROTOME

The only microtome within the reach of most high schools is the Bausch & Lomb Student's Microtome, No. 2500 which, with the universal clamp, may be bought for about $20. The barrel microtome may be used for cutting paraffin blocks, but the long paraffin process is not worth while if a better microtome is not available. In sectioning on the microtome, the greatest care must be taken to see that the block is oriented properly in order that true sections may be cut and that the sections, as they are cut, may adhere in ribbons. If the sections will not hang together or ribbon, the block should be warmed slightly. More rarely, the block is too warm and must be cooled, though such a condition is usually indicated by a failure to cut a section each time. If the ribbon curls, the block is not placed squarely with reference to the edge of the knife, or it has not been trimmed so that the sides are parallel. The razor or knife should never be sharpened just before cutting as this will frequently cause the ribbons to become electrified, making it almost impossible to handle them.

MOUNTING THE SECTION

Sections are attached to the slide by means of albumen. This is prepared by shaking together 25 cc. of pure glycerin and 25 cc. of the albumen of eggs with $\frac{1}{2}$ gm. of sodium salicylate, and filtering. A drop or two of the albumen is smeared over the portion of the slide to which the sections are to be attached and then rubbed off with a single stroke of the cloth. This albumen film is covered with water and the pieces of the ribbon of the proper length are floated upon the water. The slide is warmed very carefully in order to flatten the sections. Great care must be taken not to make the slide so warm as to melt the paraffin. The water is then removed by means of a blotter and the slide is put away to dry for 2 to 4 hours or as long as need be. The removal of the paraffin, staining, washing, etc., may be best carried on over a slop jar. The steps in the process are as follows:

1. Warm the slide gently till the paraffin melts; wash with a pipette full of xylol.

2. Wash off the xylol with a half pipette full of 100 per cent alcohol.

3. Replace the 100 with 95 per cent alcohol.

4. Stain. If the stain used is safranin, methyl green, or haematoxylin, made up in 95 per cent or some other high grade of alcohol, simply cover the sections with the stain for 5 to 10 minutes. If the stain is made up in water or a low grade of alcohol, as in the case of iron-haematoxylin, the slide should be washed successively with 75, 55, 35, and 15 per cent.

In staining with iron-haematoxylin, the slide should then be placed in water for a minute and then in a stain jar of iron alum for 10 minutes to several hours as desired. It is next rinsed in water for 2 to 3 minutes and then is placed in a stain jar of haematoxylin, in which it remains for the same length of time it did in the iron alum. The slide is now differentiated by placing again in iron-alum for a few minutes, glancing at it under the microscope every 30 seconds till the proper color is obtained. It is washed in water for 5 to 10 minutes and run up again to 95 per cent alcohol.

5. Wash with 100 per cent.

6. Cover with bergamot and clear for 5 minutes.

7. Remove excess of bergamot and add one or two drops of balsam. Start the cover at one edge and lower it slowly to avoid bubbles.

The slide should be placed, cover up, in a slide box to harden, which will require a short or long time according to the thinness of the balsam.

REAGENTS

The following simple formulae for reagents will be found useful to the teacher. Both safranin and methyl green should be made up in 2 per cent solution, 2 gms. of the stain to 100 cc. of 95 per cent alcohol. Delafield's haematoxylin is made by dissolving 1 gm. of haematoxylin crystals in 10 cc. of 95 per cent alcohol and adding it to 100 cc. of a saturated solution of ammonia alum. This mixture is allowed to ripen in a loosely stoppered bottle placed in the sunlight for three or four days, when it is filtered and 25 cc. of pure glycerin and 25 cc. of methyl alcohol are added. After standing for several days, the solution is filtered again and is then ready for use. The above solutions will keep indefinitely. For staining with iron-haematoxylin, a 2 per cent solution of ammonio-ferric-alum in distilled water is used and a $\frac{1}{2}$ per cent solution of haematoxylin in distilled water. Neither of these solutions keep very well and should be made up in small quantities. The formula for Flemming's solution (1) is 60 cc. 1 per cent solution of chromic acid in tap water, 5 cc. 1 per cent solution of osmic acid, and 1 cc. glacial acetic acid. Glycerin jelly may be prepared by soaking 5 gms. of pure white gelatin in 50 cc. of distilled water, adding 50 cc. of pure glycerin and 1 gm. of phenol. The usual solution of iodin consists of $\frac{1}{2}$ gm. of metallic iodin, 1 gm. of potassic iodid and 100 cc. of water. Glycerin is made up in 50 per cent or 12 per cent solution in water, according to whether it is used for plasmolysis or for general use. Potash is used in 10 per cent or 25 per cent solution in water. For ordinary use commercial balsam should be diluted $\frac{1}{3}$ to $\frac{1}{2}$ its volume with xylol or chloroform. A convenient and sufficiently accurate formula for diluting alcohol is the following: desired any per cent between 10 and 30, take as many cubic centimeters plus one of 95 per cent alcohol and add water to make up 100 cc.; between 30 and 50, add two to the grade desired; between 50 and 70 add four, and between 70 and 90 add five.

REFERENCES IN THE TEXT

Unless otherwise specified all references in the text will be to Bessey's "Essentials of Botany," seventh edition. References in Roman numerals are to plates in Part I and II of the Flora of Nebraska. *The number following the directions for drawing indicates the scale to which the object is to be drawn.*

PLANT STRUCTURE OR HISTOLOGY

THE CELL

Cell wall (6)—

PRIMITIVE WALLS—

1. *Protococcus viridis,* green slime: scrape off a little of the green growth on the outside of flower pots and carefully pick it apart; note the extreme thinness of the cell-wall except in certain resting stages, where it is a thick colorless band; draw several cells or plants, showing wall and contents; 5.**
   The nucleus is not evident; the body which suggests it is usually a pyrenoid, a small bit of cytoplasm in which starch is stored. (f. 66, *a.* 135.)

*2. *Spirogyra sp.,* pond scum: mount a few filaments and note carefully the side and end walls; describe the wall, thinness, color, structure, etc., and draw one cell showing these points; 1. The nucleus usually shows very plainly in the center of the cell surrounded by radiating threads of protoplasm. The chloroplasts are green, ribbon-like bodies of protoplasm disposed spirally in the cell.
   Is the cell wall composed of distinct layers?

** Note remark in italics—bottom of page 30.
* Spirogyra sp. The "sp." indicates *any* or *no particular* species.

Is it lined on the inner surface with cytoplasm or with cell sap? (141, f. 73, p. 142.)

3. *Funaria hygrometrica,* moss: remove one or two leaves from the stem and mount them; the cells are here united into a tissue and the wall between two cell cavities is a double one formed by cementing the two walls together; draw a group of four or five cells, showing the wall but disregarding the green chloroplasts; 1.
Do you find any evidence of the double wall? (f. 8, p. 13.)

MODIFIED WALLS—

4. *Hibiscus sp.,* mallow: mount a few pollen grains, taking care not to crush them; draw one cell showing the external modifications of the wall; crush the cell and note the contents; 1. From the crushed cells it is possible to tell whether the spines arise from the thickening or from a pushing-out of the wall. (f. 149, p. 252.)
5. *Puccinia graminis,* grain rust: remove a spore dot or sorus of the black rust or resting stage and pick it apart; note the varying thickness of the wall in different parts of the same cell and in corresponding parts of different cells; draw two or three spores showing various thicknesses of the wall: 2. How many cells in each spore? Has the stalk cell any protoplasm? Where is the

wall the thickest? Why? How does the growth of the spores in masses explain the varying thickness of wall in the same spore? (191, f. 113, II, III, p. 192; f. 114, p. 194.)

6. *Pirus communis,* pear: cut longisections of the stems of mature pears, stain in safranin and mount in balsam; note the square stone cells, describing minutely the structure of the greatly thickened wall; note the canals which radiate from the small cavity and the striations which run parallel to it; 2.

Explain the pits which appear in the back wall? Why do the canals of adjacent cells coincide? Why are the striations concentric? Do any canals branch? Can you find any indication of the original thin wall between the cells? (23, f. 14, p. 24.)

Cell formation (9)—

FISSION—

7. *Nostoc commune,* jelly chain: crush and separate the thallus before mounting; select a filament in which the cells are of different length; note that certain cells are just twice as long as others, while some intermediate in length show a slight constriction on either side; draw 10 or 12 cells of a filament showing a variety of stages, preferably including the heterocyst; 4.

The normal cells are globose or somewhat elliptical, those ready for fission about twice as long. Fission starts by the pinching in of the side walls and is completed by the formation of an end wall between the points of constriction. In Anabaena, a related plant, the growth and pinching in of the wall occur at the same time. The heterocyst is a clear yellowish cell found at intervals in the filament. (f. 61, p. 126.)

8. *Oscillatoria tenuis,* thread slime: mount a few filaments and note the compact way in which the cells are united; draw one filament, giving especial attention to the curved apical portion; 1.

Do all the cells undergo fission? What is the purpose of the apical cell? Is there a sheath about the filament? Explain why some cells are twice the length of others. How many movements has the filament? (f. 61, p. 126.)

BUDDING—

9. *Saccharomyces cerevisiae,* yeast: make a yeast culture by adding a small amount of "yeast foam" to a 10 per cent solution of cane sugar and keep at 30° to 35° C. for 24 hours; mount a drop of the solution and examine for budding cells; draw several cells showing different stages in the formation of a single bud, also one or two groups showing repeated budding; 3.

The nucleus does not show; the central body is a vacuole. Are there any chloroplasts present? Does one cell ever give rise to more than one bud? Distinguish between budding and fission. Is a new cross wall formed in budding? Stain lightly with iodin; what are the blue bodies? What part do they play? (189, f. 112, p. 190.)

UNION—

10. *Spirogyra nitida,* pond scum: mount a few fruiting threads and examine those parallel ones in which one thread is empty, the other filled with an elliptical resting spore or zygote; draw four cells, two from each filament, paying especial attention to the conjugating tubes which connect them; $\frac{2}{3}$.
How is the zygote formed? How does the protoplasm cross from one cell to the other? Explain the origin of the conjugating tubes. Why should the zygote have a thick wall? Is any protoplasm left in the clear cell? (143, f. 73, p. 142.)

Cell contents—

PROTOPLASM (1)—

11. *Lycopersicum esculentum,* tomato: cut thin transections of a young flower stalk, taking care not to injure the hairs; examine the basal cells of the latter for streaming protoplasm and nucleus; draw a typical cell showing the threads of protoplasm, nucleus, nucleolus, vacuoles, and the pale green bodies, the plastids; 1.

Is there a layer of protoplasm lining the wall of the cell? Why? Does the protoplasm move in a definite direction? Does it pass from one cell to another? Does the nucleus move? Note the effect of iodin. (f. 26, p. 43.)

12. *Nitella flexilis,* stonewort: remove the whorl of cells from the apex of a growing leaf and mount with little pressure; draw in optical section a cell in which the protoplasm is streaming actively, paying especial attention to the structure of the latter; 1. The cell contains a number of oblong nuclei which can not be seen without staining. What are the small green bodies along the inner surface of the wall? Do they move? Do the granules move more slowly at the sides or in the center of the cell? Does the protoplasm flow more than one way in the same cell? Contrast this movement with that of the protoplasm of the tomato hair.

CHROMATOPHORES (2, 12)—

CHLOROPLASTS—

13. *Funaria hygrometrica,* moss: remove and mount two or three leaves; the lower oblong cells of the base of the leaf show the individual plastids best; draw a cell in which are shown the various stages of the fission of the plastids, giving to each its exact form and position; stain with iodin; 2.

Contrast the fission here with that of the cells of Nostoc. Do the plastids contain starch grains? Do they have a distinct wall or membrane? (f. 8, p. 13.)

14. *Zebrina pendula*, wandering Jew: mount a thin longisection of the stem from just beneath the epidermis; stain very lightly with iodin; draw one cell showing the various stages of chloroplasts and starch grains; 1. How many starch grains in a plastid? In what part of the latter do they occur? Do you see any starch grain not in contact with a plastid?

CHROMOPLASTS—

15. *Tropaeolum majus*, "nasturtium": tear a piece of petal into small bits and mount; the bright yellow color is due in most cells to numerous yellow balls of protoplasm, in a few cells the chromoplasts are needle- or crescent-shaped; draw one cell of each kind; 2. Stain with iodin.
Do these chromoplasts contain starch? Do they show fission? Which are the normal ones, the spherical or needle-shaped?

LEUCOPLASTS—

16. *Zebrina pendula*, wandering Jew: slip the point of the scalpel beneath the epidermis of the stem and strip the latter off free from green cells below; the nucleus usually occupies the center of the clear epidermal cells,

surrounded by a few threads of protoplasm which run to the wall; the leucoplasts are round clear bodies lying upon the nucleus and occasionally found scattered in the cell; 1. Stain with iodin.

Do the leucoplasts divide? Do they contain starch? Is there protoplasmic movement in the threads? Has this anything to do with the leucoplasts?

STARCH (14)—

17. *Solanum tuberosum,* potato: cut a section from the fresh surface of a tuber; draw two cells showing various grains and paying particular attention to the striations of the latter; 2. Stain with iodin to demonstrate if possible the presence of protoplasm in the cell.

Do you find any plastids in the cell? What is the hilum? Explain how the striations arise. Why is the grain called excentric? Explain its form.

18. *Pisum sativum,* garden pea: cut a few thin shavings from the flat surface of a split pea and mount them in weak alcohol; draw one cell showing the grains of starch with their striations and the small granules in which they are imbedded; 1. Stain with iodin.

Are the grains concentric or excentric? Is there a hilum? Note the thickened cell wall. Explain the triangular space at the corners of the cells. (f. 9, p. 15.)

ALEURONE (16)—

19. *Phaseolus vulgaris,* bean: mount in weak alcohol a few shavings from the flat surface of a split bean; stain lightly with iodin; draw one cell showing wall, starch, and aleurone; 1.

Replace the alcohol with water. What happens? Are the aleurone grains definite in size or shape? Do they have striations? Explain their position in the cell. Does aleurone give the same color with iodin that living protoplasm does?

20. *Triticum sativum,* wheat: divide a grain transversely and cut shaving sections across the edge; stain one section lightly with iodin to locate the aleurone and starch; draw a strip three or four cells wide extending from the outer bran into the mass of starch; 1.

Where is the aleurone found? Is it distinct from the starch? Do you find starch anywhere in the aleurone cells or vice versa? Why is graham bread more nutritious than wheat bread? Contrast the position of the aleurone in the bean and the wheat.

CRYSTALS (17)—

21. *Zebrina pendula,* wandering Jew: make a thin longisection of the stem; occasionally cells will be found filled with crystals, but usually the latter are scattered about; if

possible draw both sorts of crystals in position in the cells; with the long ones it may be necessary to draw several crystals separately; 1.

What two shapes do the crystals assume? Do both forms occur in the same cell? Are the crystal cells found in definite positions in the tissue? Add a drop of hydrochloric acid at the edge of the cover. What happens? (f. 12, p. 17.)

22. *Begonia sp.*, begonia: cut a thin longisection of the stem; draw a group of several cells, showing definitely the position of the crystal-bearing ones and paying especial attention to the structure of the crystal itself; $\frac{2}{3}$.

Do the crystal cells have a definite position in the tissue? Does there appear to be any relation between this and the long bundles of fibers in the stem? How many crystals in each cell? Why? Is the crystal a single one or a group of crystals? What is the usual shape of the individual crystals? (f. 12, p. 17.)

THE TISSUES

Primary tissue (21, 36)—

MERISTEM—

23. *Hyacinthus orientalis*, hyacinth: root tips are obtained by growing the bulbs in flower pots, or, better, in wide-mouthed bottles or

bulb glasses; make very thin transections of the tips and, if possible, longisections also; note the characteristics of the individual cells, pay especial attention to their form and the way in which they are united to constitute a tissue; draw a group of 8 or 10 cells; 1. Stain with iodin.

Explain the large nucleus and the abundance of protoplasm. Are the vacuoles few or many? Why should the cells show such regularity in size and arrangement? Do you find any intercellular spaces. Why? Do the cells contain starch? Plastids? Why? Do you find more than one nucleolus in any of the nuclei? Can you distinguish the two component walls in the double wall between two adjacent cell cavities? (f. 25, p. 37.)

Secondary or modified tissues—

PARENCHYMA, Soft tissue (21)—

24. *Begonia sp.*, begonia: mount thin trans- and longisections of the stem; note the differences which the cells show in the two sections and draw a group of 4 or 5 cells from each; $\frac{2}{3}$. Stain with iodin.

Contrast the cells of soft tissue with those of meristem with respect to size, shape, arrangement, amount of protoplasm, nucleus, wall, vacuoles, etc. Explain the intercellular spaces. Are they found in longisection? Why? Do you find starch or plastids?

Explain why the transection of the cell is different from the longisection. Is the cell wall thickened? Add a small drop of strong sulphuric acid to sections stained with iodin; the cellulose walls turn a dark blue, the characteristic test for this substance. (f. 40, p. 62.)

COLLENCHYMA, Thick-angled tissue (22)—

25. *Begonia sp.,* begonia: mount a thin transection of the stem; the thick-angled cells are found directly beneath the single-rowed epidermis and are easily recognised by the bright thickened places in the corners of the cells; draw a group of 8 or 10 cells showing how the cells with greatly thickened corners next the epidermis pass gradually into the soft tissue cells of the interior of the stem. Are there any cells in which the walls are thickened at the sides as well as in the corners? Can you find any trace of the original wall in the thickened angles? Do the thickenings show any layers? Why? Do you find any nuclei or plastids? What purpose does the thickening of the angles serve? Determine by the iodin-sulphuric acid test* whether the angles are composed of cellulose. Beta vulgaris, beet, leaf-stalk: Micrampelis lobata, wild cucumber, stem. (f. 13, p. 22.)

* Cf. line 3 above.

SCLERENCHYMA, Stony tissue (23)—

26. *Pirus communis,* pear: make small thin trans- and longisections of the fruit-stalk of the pear; stain in safranin for 10 minutes and wash in 95 per cent alcohol; the sections may be mounted in water, or they may be run up and mounted in balsam in the usual way; the stone fibers are found in dense white bundles arranged in a circle in the center of the stem, the stone cells are scattered here and there between the bundles and the outside of the stem; in the longisection they occupy the same places, but are best recognized by their difference in shape; draw a group of 3 stone cells, preferably from the longisection and a group of stone fibers from each section; 1.

Contrast stone cells and stone fibers in both sections, with respect to shape, size, position, arrangement, wall, canals, contents, etc. To which is the term isodiametric applied? Do the radiating canals of two adjacent stone cells coincide? Why? Explain the striations in the stone cells. Why are they concentric? Explain the pits in the back wall. Is there a nucleus? Why? Add anilin sulphate to the sections and, in 10 minutes, a drop of concentrated sulphuric acid; the yellow color is the characteristic test for stony tissue. (f. 14, p. 24.)

FIBROUS TISSUE (24)—

27. *Fraxinus lanceolata,* green ash: split a small bit of twig and make thin trans- and radial longisections at the edge in such a way as to pass through the bark and the outer part of the wood; the bark will show a ring of bright white bundles of thick-walled fibers, bast, in the green parenchyma, and the woody porticn will show a compact tissue made up of wood fibers; in the longisection the bast fibers are readily distinguished by their position and thick walls; draw from the transection a bundle of bast fibers, paying especial attention to the striations of the wall, and a group of wood fibers; draw from the longisection a group of bast fibers, showing, if possible, the ends of scme, and a number of wood fibers, showing the various ends and the way they join in the tissue; 1.
Compare bast fibers and wood fibers in both sections. Show how each is best suited to its position. Do you find any indication of the original thin wall in the present thick wall of the fibers? Do the walls of the wood fibers have layers? Are there cells contents in either sort of fiber? Do the walls show canals or other markings? Explain why the ends are tapering. Make the lignin or wood test with anilin sulphate-sulphuric acid. (f. 15, p. 25.)

Sieve tissue (28)—

28. *Micrampelis lobata,* wild cucumber: cut thin trans- and longisections of the stem, taking care that the latter pass through the fibrovascular bundles, the long threads which project into the central cavity and contain openings visible to the eye; in the transection, the center of each bundle is occupied by three or four large circles, cross-sections of vessels; next these on either side are several rows of very small, mostly rectangular cells, and imbedded in these, or just outside them, a row of larger polygonal or round openings—the sieve tubes; in the longisections the tubes are recognized by their position on the outside of the bundle and by the broad masses of protoplasm, sometimes callose, on either side of the end partition or sieve plate; if the transection is cut near a sieve plate, the perforations of the latter will appear as small black points in the cross-section of the tube; draw from the transection the sieve portion of the bundle, showing the point just mentioned, and from the longisection a number of tubes showing the cross-section of the sieve plates and the funnel-like protoplasmic column on either side; notice the small rectangular companion cell, touching the sieve tube, with its nucleus and densely granular protoplasm; 1.

Are the two protoplasms on either side of the sieve plate in connection? Are the sieve tubes nucleate? Do you find either starch or plastids present? Make the cellulose test. Cucurbita pepo, pumpkin, leaf-stalk. (f. 18, p. 29.)

MILK TISSUE (26)—

29. *Euphorbia splendens,* spurge: make trans- and longisections of the stem; in the transection, the milk tubes appear as small thick-walled circles just outside the ring of woody tissue in the center, in the longisection as branching tubes filled with a sticky granular liquid; draw several tubes in longisection, showing position in the tissue, contents, etc.; 1. Stain with iodin.

What are the bone-shaped granules in the tubes? Do you find plastids or nuclei? Do you find striations in the wall of the tube? Asclepias syriaca, milkweed, stem. (f. 16, p. 27.)

TRACHEARY TISSUE (30)—

TRACHEAE OR VESSELS—

30. *Impatiens balsamina,* balsam, touch-me-not: cut radial longisections of the stem; the fibrovascular bundles will show a succession of cylindrical vessels with the walls thickened in various ways; the simplest have circular or spiral thickenings on the inner surface, these passing into net-like or reticulate

markings and the latter finally giving rise to pits; draw a group of vessels showing the various stages of development from ringed to pitted walls; 1.

Have the vessels nuclei or contents? Do you find any cross-partitions? Any hint of their former presence? What is the purpose of the thickenings? How were they formed? Make the lignin test. (f. 20, p. 31.)

TRACHEIDS (33)—

31. *Pinus austriaca,* Austrian pine: make transverse and both radial and tangential longitudinal sections of a young twig; the entire woody tissue, with the exception of the occasional medullary rays, consists of tracheids; draw a group of tracheids from each of the three sections, paying especial attention to the bordered pits in the walls; 1. The transection and the tangential longisection will give a cross-section of the bordered pits; the radial longisection a front view of them.

Explain the structure of the pits, especially the border. Do they occur in rows? Why? How many parts to the cell wall in the transection? Is there any suggestion of canals? Do the tracheids have contents? Sequoia sempervirens, redwood. (f. 23, p. 33.)

THE TISSUE SYSTEMS

Epidermal system (40):

EPIDERMIS—

32. *Agave americana,* century plant: make thin transections of the epidermis of a young leaf; draw 4 or 5 cells, paying especial attention to the cuticle, the thick outer wall; 1.
Do you find a nucleus or plastids? Is there any protoplasm present? How is the outer wall thickened? Does it show layers? Make the cellulose and lignin tests. What are the outer layers?

STOMATA OR BREATHING PORES (44)—

33. *Agave americana,* century plant: in the sections made above, the epidermis shows openings into the interior of the leaf, which are guarded by peculiarly modified cells; draw one stoma, showing the epidermal cells, guard cells, and the parenchyma cells which surround the air chamber; 1.
What are the guard cells? What is their function? Do they make starch? Why? Are they closed or open in your section? Why are they thin-walled? What is the purpose of the chimney formed by the epidermal cells? What is the purpose of the air chamber beneath the stoma? Does it have any connection with the spaces between the cells of the leaf? Stain with iodin.

34. *Begonia sp.*, begonia: strip a small piece of epidermis from both surfaces of a leaf and mount in weak alcohol; if there is sufficient difference to warrant, draw a group of stomata from each surface; 2.

Compare the top view of the stoma thus obtained with the sectional view in the experiment above. Are the stomata single or in groups? Contrast the guard cells with the epidermal cells. Are any of the stomata open? Do the walls of the guard cells next the opening show any peculiarity? Why? Which has the larger number of stomata, upper or lower surface? Why? Under the low power count the number of stomata in a given space. (f. 29, p. 44.)

HAIRS (42)—

35. *Lycopersicum esculentum*, tomato: mount thin transections of the upper part of a young stem; note the three sorts of hairs, paying especial attention to the way in which they arise from the epidermal cells; draw a hair of each sort giving in detail its connection with the epidermis; 1. The largest hair may well be drawn to a scale of $\frac{2}{3}$ or $\frac{1}{2}$.

Compare the origin and structure of the three sorts of hairs. From this can you suggest any explanation of their function? In what way do the cells of the hairs differ from epidermal cells—from soft tissue cells? (f. 26, p. 43.)

Fibrovascular system (46):

COLLATERAL BUNDLES—CLOSED TYPE—

36. *Zea mays,* corn: mount thin transections of the stem; draw a complete bundle; 1.
Distinguish the wood or xylem portion of the bundle from the sieve or phloem portion. Which is on the side toward the surface of the stem? Do you find any companion cells with the sieve tubes? What is the bundle sheath? Is it complete? Point out the various kinds of tissues which make up the bundle? Is there any meristem or growing tissue in it? What is the position of the bundles in the stem? (f. 30, p. 47.)

OPEN TYPE—

37. *Impatiens balsamina,* balsam: mount thin trans- and longisections of the full-grown stem; draw a bundle in both views, showing in the transection the ring of meristem or cambium, upon which the bundles are strung, at either side; 1.
Compare the position in the stem of the open and of the closed type of bundle. What relation has the ring of cambium to this fact? Locate the xylem and phloem parts of the bundle. What kind of tissue separates them? Point out the wood fibers, tracheary

vessels, sieve tubes, etc. Which parts are lignified? Which are composed of cellulose? Do you find any young bundles? How do they arise? How are they different from the old ones? (f. 20, p. 31; f. 31, p. 48; f. 32, p. 49.)

RADIAL BUNDLES—

38. *Zea mays,* corn: make thin transections of well-developed roots; make a diagrammatic sketch, showing the position of xylem and phloem in the bundle and a detailed drawing of a segment, showing the pith, two xylem and phloem rays, and the corresponding portion of the bundle sheath; 1.

How many radial bundles in each root? What is its position? Contrast the radial bundle with both types of the collateral. Is there any cambium in the bundle? (f. 33, p. 51.)

CONCENTRIC BUNDLES—

39. *Pteris aquilina,* brake fern: cut thin transections of the root-stalk; draw a small bundle or a portion of a larger one; 1.

Is there more than one bundle in the stem? What of their position? Is there any cambium present? Any sieve tissue? Compare with the radial bundle. (f. 36, p. 54.) Make diagrammatic drawings of the four transections studied above, showing the relativ number and position of the bundles.

REDUCED BUNDLES—

40. *Populus deltoides*, cottonwood: make thin superficial sections from the under surface of the leaf, cutting through some of the secondary veins; draw a segment from the reduced bundle thus exposed, showing the leaf parenchyma, mesophyll, on either side and the detail of the bundle; 1.

Compare the reduced bundle with the longisection of the open bundle of Impatiens. What tissues and vessels are still found in it? Is the bundle sheath still present? Are the reduced bundles of the leaves connected with the complete ones of the stem? Point out why this must be so both structurally and functionally. (f. 37, p. 56.)

Fundamental system (57):

INTERCELLULAR SPACES—

41. *Scirpus lacustris*, bulrush: make thin transections of the stem; note the extremely large intercellular spaces, across which are stretched thin plates or diaphragms of two different patterns; draw an intercellular space with its walls and diaphragm, $\frac{1}{2}$, and a few cells from both sorts of diaphragms, 1. Compare these spaces with the small triangular spaces so common in soft tissue. Do you find connecting forms between the latticed and the stellate diaphragms? Is there an explanation of these spaces and

diaphragms in the fact that the bulrush is a water plant? Point out the tissues of the fundamental system. (f. 41, p. 63.)

SECRETORY PASSAGES—RESIN CANALS—

42. *Pinus austriaca,* Austrian pine: make thin transections of the leaf; the center is occupied by the fibrovascular system, the edge by the one-layered epidermis; the remainder is the fundamental system, in the chlorophyll-bearing tissue of which are found the resin or turpentine canals; draw a canal showing the detail; 2.

How many tissues in the fundamental system of the pine leaf? What is the function of the fibrous tissue at the edge? How many parts in the canal? What is the purpose of the outer row of cells? What kind of fibers are they? What is the function of the cells next the cavity of the canal?

MUCILAGE CANALS—

43. *Sagittaria latifolia,* arrowhead: make a thin transection of the petiole; the mucilage canals are found where the walls of the intercellular spaces join; draw a couple of canals, showing their location and structure; 1½.

From the spaces of the stem, in what sort of places must the arrowhead grow? Are there any diaphragms? Point out the different systems and tissues. How many parts to the canal? (f. 42, p. 63.)

CORK (59)—

44. *Sambucus canadensis,* elderberry: make a thin transection of the stem through the raised corky masses or lenticels; draw the cork mass in the lenticel and the cork-producing meristem or phellogen just beneath; 1.

Compare cork with parenchyma. Make the cellulose and lignin tests with it. Why is the lenticel filled with cork? What is the function of cork tissue? (f. 38, p. 59; f. 60, p. 39.)

STRUCTURE AND CLASSIFICATION

BRANCH PROTOPHYTA

Class Schizophyceae

ORDER CYSTIPHOREAE

FAMILY CHROOCOCCACEAE

1. *Gloeocapsa arenaria:* draw several colonies, showing the development from a single-celled colony to those having 8 or 16 cells; 3.

   Are the cells all alike? Explain the layered wall. Why are the cells round or spherical? Do they show any of the usual cell contents? Can you distinguish a nucleus or a definite cytoplasm? How do the cells increase? Point out the different steps in the process. Do you find any movement of the cells? Compare the cell of this simple plant with an ordinary parenchyma cell. The plants contain chlorophyll though this is concealed by a blue green coloring matter called phycocyanin which is present throughout the entire branch. Each cell contains a single cylindrical plastid; the granularity of the cytoplasm is due to granules of food material of uncertain composition, probably related to aleurone. (f. 60, p. 126; I, 3.)

ORDER NEMATOGENEAE

FAMILY NOSTOCACEAE

2. *Nostoc commune:* draw a thread showing the heterocysts and the different stages of fission in the vegetative cells, also the spores if any are present; 2.
   What is the character of the thallus or mass in which the filaments are imbedded? Is fission here essentially the same as in Gloeocapsa? In what way do the vegetative cells differ? Contrast spores and heterocysts with the vegetative cells from which they are derived. Point out the steps in evolution by which a Gloeocapsa might have become a Nostoc. Show why the latter is higher. What other ways of increase has Nostoc besides the fission of its vegetative cells? (f. 61, p. 126: I, 4.)

FAMILY OSCILLATORIACEAE

3. *Oscillatoria tenuis:* draw one or two threads, paying especial attention to the tip and to fission and noting the disposition of the granules; 2.
   Do you find spores and heterocysts? Compare the fission with that of Nostoc. Explain the tip cell. How many movements have the filaments? Show how in one sense Oscillatoria is lower than Nostoc; in another higher. Does it have a definite thallus? In addition to fission, propagation occurs by means of the breaking up of the filament into short pieces which slip out of the thin sheath and grow into new filaments. These

bodies are called hormogones and are often seen forming in the filament, at which point the thin sheath usually becomes visible. (f. 61, p. 126: I, 16.)

FAMILY SCYTONEMATACEAE

4. *Scytonema cinereum:* draw a portion of a thread, showing one or two false branches and the heterocysts, also the sheath and different stages of the vegetative cells; 2.
Point out the differences between Scytonema and Oscillatoria. Do these filaments move? Does the presence of a thick sheath explain this at all? Are there any spores? Hormogones? Why do we speak of false branching? Show why Scytonema is higher than Oscillatoria and Nostoc. What sort of a thallus does it form? (II, 24.)

FAMILY RIVULARIACEAE

5. *Gloeotrichia pisum:* draw a complete thread, showing especially the vegetative cells which are undergoing fission; 1.
What sort of a thallus has this plant? Is it like any you have had? How are the filaments arranged in the thallus? Does the thread move? Why? Does it have spores and heterocysts? Does fission occur anywhere in the thread or at a definite place? Why? Explain the long cells of the lash at the tip. Do they divide? What of the sheath? Show how a Gloeotrichia might have developed from a Scytonema. (III, 33.)

FAMILY BACTERIACEAE

6. *Bacillus subtilis:* keep a bottle containing pond or creek water and a few algae tightly corked for 24 to 48 hours; a drop of the culture will show under the high power great numbers of short thread-like colorless plants moving about actively in the field; if they can not be observed readily, kill and stain them by adding a drop of gentian violet at the edge of the cover; draw several plants; 5.

   Account for the absence of chorophyll. Is there a distinct wall? Can you distinguish cytoplasm or nucleus? Are the cells all alike except for size? Is there any trace of fission? Contrast the movement with that shown by Oscillatoria. Show what changes are necessary to derive Bacillus from Oscillatoria. (f. 62, p. 128.)

7. *Spirillum undula:* in the above culture there will be found bacteria resembling Bacillus but exhibiting a spiral or snake-like motion; draw several of these cells, paying especial attention to the turns of the spiral; 5.

   Compare Spirillum and Bacillus. Docs the former always move with the same end forward? What does this indicate? Stain with gentian violet if necessary. (f. 62, p. 128.)

BRANCH PHYCOPHYTA

Class Chlorophyceae

ORDER PROTOCOCCOIDEAE

FAMILY PLEUROCOCCACEAE

8. *Protococcus viridis:* remove and mount a little of the green crust which grows on flower pots in greenhouses and upon the bark of trees; a plentiful supply of the plant may be obtained by teasing apart the grey lichens which grow on trees; draw several single plants and also a cluster; 2. Is there a definite wall? Plastids? Note the different stages of fission. Compare with the same process in the blue green slimes. Are the cells in definite colonies or are they simply clustered? Compare Protococcus with Gloeocapsa. (f. 66, p. 135: IV, 11.)

9. *Scenedesmus obliquus:* draw several groups, showing the cells in 4's, 8's, etc.; 2.
Do the cells occur in definite colonies? Can you explain this grouping? Contrast the fission with that shown by Protococcus. Do the cells have pyrenoids? Are any of the cells pointed or spiny? Why? Do you find the protoplasm rounding up in any of the cells or escaping as a spherical moving cell, the zoogonid? Sometimes the latter are found swimming about in the mount in great numbers. (f. 66, *b,* p. 135: IV, 10.)

FAMILY DESMIDIACEAE

10. *Closterium lanceolatum:* draw one cell, paying especial attention to the structure; each plant is

composed of two so-called half-cells, the separation of the two being indicated by a clear space in the center of the cell; at either end is a clear bubble or vacuole filled with tiny oblong bodies resembling bacteria in active motion; these are crystals of gypsum, calcium sulphate, which are to be regarded as waste products of the plant; 1. Do you find any evidence that the wall is composed of two parts or valves? How many plastids are there? Do they run the length of the plant? Do they lie against the wall or centrally in the cavity? Where are the pyrenoids? Contrast a Closterium with a Protococcus cell. Do the cells move? (f. 71, p. 139: V, 1.)

FAMILY BACILLARIACEAE

11. *Navicula viridis:* draw one live cell, showing the plastids and if possible a dead one showing the striations of the silicious wall; 1.
To what is the brown color due? Do the cells move? Are there any pyrenoids? Contrast the plant with Closterium. (f. 72, p. 140.)

FAMILY ZYGNEMACEAE

12. *Spirogyra nitida:* draw a cell from a vegetative filament showing the details of structure; $\frac{2}{3}$; from filaments in conjugation, draw three groups of conjugating cells, the first showing the conjugating tubes forming and the plastids still intact, the second, the union of the conjugating tubes and the passage of the condensed protoplasm from one cell into the other, and the third the formation of the spore or zygote; $\frac{2}{3}$.

How many chloroplasts in the vegetative cell? Where are the pyrenoids? Is a nucleus present? Discuss fully the details of conjugation as gathered from the different filaments. Does the zygote have a thick wall? What is the purpose of the zygote? Compare Spirogyra with Closterium. (f. 73, p. 142.)

FAMILY MUCORACEAE

13. *Ascophora mucedo:* examine without cover-glass under the low power a tuft of erect threads or hyphae bearing the black sporangia; draw such a tuft, and under the high power a single stalk with its sporangium and spores; 1.

Why is the plant colorless? What effect has this habit had upon the cell partitions? How are the little tufts formed? How do the spores escape from the sporangium? Do you find any root-like structures? The reproduction is by conjugation; it is, however, practically impossible to obtain it in the ordinary cultures. (fs. 74, p. 144; 75, p. 145; 76, p. 146: XIV, 4.)

ORDER SIPHONEAE

FAMILY VAUCHERIACEAE

14. *Vaucheria hamata:* draw a portion of the main filament showing a lateral branch bearing oogones and antherids, also the zoosporangium if present; 1.

Is the main filament one-celled or many-celled? How is the zoospore formed? Describe the oogone and antherid in detail. Compare them with the reproductive cells in Spirogyra. Do you find any chloroplasts, pyrenoids, or nuclei? (f. 78, p. 150; XII, XIII.)

FAMILY PERONOSPORACEAE

15. *Peronospora parasitica:* mount some of the mycelium in weak alcohol and draw one of the branched stalks or conidiophores with its conidia; macerate a portion of the leaf and draw an oogone and antherid; 1.
Compare Peronospora with Vaucheria. Explain the reduction of the plant body. Why does the plant have conidia instead of zoogonids? In what ways does it resemble Ascophora? (f. 80, p. 153, f. 85, p. 155; XVI, 21.)

ORDER CONFERVOIDEAE

FAMILY ULOTRICHIACEAE

16. *Microspora abbreviata:* draw a filament showing the detail of the cells and the formation of gonidia; 2.
What are the chloroplasts like? How many in each cell? Do you find pyrenoids or a nucleus? How do the zoogonids arise? Do you find more than one kind? What is their function? What important differences between Microspora and Vaucheria? (f. 86 B, p. 157.)

FAMILY OEDOGONIACEAE

17. *Oedogonium nodulosum:* draw a filament showing the oogones and the dwarf males which bear the antheridia; 1.
Describe the oogones and dwarf males in detail.

In what respects do these organs differ from those of Vaucheria? What is the oospore? How does it arise? Why should there be several antherids for each oogone? Describe the structure of the vegetative cell. (f. 87, p. 159; f. 88, p. 160.)

CLASS PHAEOPHYCEAE

ORDER PHAEOSPOREAE

FAMILY ECTOCARPACEAE

18. *Ectocarpus litoralis:* draw a portion of a filament showing the branching and two or three stages in the development of the plurilocular sporangium; draw also a row of unilocular sporangia; 1.

What is the color of the plant? What is it due to? Is chlorophyll present? Do you find pyrenoids or plastids? How do the plurilocular sporangia arise? The unilocular? How do their respective zoogonids differ? Compare Ectocarpus with Microspora.

ORDER FUCOIDEAE

FAMILY FUCACEAE

19. *Fucus fastigiatus:* mount a thin transverse section of the fruiting tip and draw one of the pit-like conceptacles, paying especial attention to oogones, antherids, and sterile hairs, the paraphyses; 1.

How does the tissue of the tip differ from parenchyma? Why should the fruiting organ be sunken in the tissue? What is the purpose of the paraphyses? Describe the antherids and oogones. Distinguish between isogametes and heterogametes. Illustrate. (f. 90, p. 164; f. 91, p. 165.)

BRANCH CARPOPHYTA

CLASS RHODOPHYCEAE

ORDER FLORIDEAE

FAMILY RHODOMELACEAE

20. *Polysiphonia fastigiata:* draw a portion of the main stem bearing a tetrasporic branch; also a branch showing antherids and one with a cystocarp; 1.

Compare tetraspores with macrozoogonidia. What important differences between the cystocarp and the oogone. Describe the plant body. To what is its color due? Why is this plant higher than Oedogonium or Fucus? (f. 95, p. 172.)

CLASS ASCOMYCETES

ORDER PERISPORIACEAE

FAMILY ERYSIPHACEAE

21. *Uncinula salicis:* scrape a number of the spore fruits from the leaf of the host and mount in weak alcohol; draw a perithecium under the low power with especial attention to the appendages; crush the perithecium and draw the cluster of spore sacs or asci, with their spores; 1.

What kind of a plant is this? How does it obtain its nourishment from the host? Do you find any vegetative filaments? Are there any differences between the perithecium, and the cystocarp of Polysiphonia? Upon what leaves do you find this fungus? Have you seen a similar fungus on any other plant? How can the spores escape from the perithecium? (f. 99, p. 176.)

ORDER TUBERALES

FAMILY TUBERACEAE

22. *Tuber melanosporum:* cut a thin section of the spore fruit and draw three or four asci in position among the sterile threads; 1.
Describe the spore fruit? Where is it found? Are any vegetative filaments present? What evidences of relationship between this plant and Uncinula? How do the spores escape? (f. 102, p. 180.)

ORDER PYRENOMYCETALES

FAMILY HYSTERIACEAE

23. *Hysterographium fraxini:* cut a cross-section of the perithecium and make a diagrammatic drawing showing the position of the asci and paraphyses; also draw a single ascus with paraphyses and spores; 1.
Describe the perithecium and its contents. How is this plant different from Uncinula? How do the spores escape? Where is the plant found? Is it a parasite or saprophyte? Why? (f. 104, p. 182.)

ORDER DISCOMYCETALES

FAMILY PEZIZACEAE

24. *Sepultaria scutellata:* cut a cross-section of the spore fruit, the apothecium, and make a diagrammatic drawing showing the position of asci and paraphyses; also draw one ascus with its spores and paraphyses; 1.

    Describe the structure of the apothecium. Contrast this plant with Hysterographium. Which do you think the higher? Why? How do the spores escape? How do they differ from those of the preceding plant? Where is this plant found? Is it a parasite? Why? What is the purpose of the spiny hairs on the outside? (fs. 106, 107, p. 185.)

FAMILY PARMELIACEAE

25. *Physcia stellaris:* cut a cross-section of the apothecium through the disk or hymenium and the vegetative body or thallus; draw a segment extending from the hymenium through the thallus, paying especial attention to the asci and the Protococcus cells of the thallus; 1.

    Describe the apothecium and the thallus in detail. In what important respects does this plant differ from the preceding ascus-bearing plants? Is this union of Protococcus and fungus favorable to the former? Why? Where is this plant found? How would you recognise a lichen? (f. 110, p. 187.)

ORDER UREDINALES

FAMILY UREDINACEAE

26. *Puccinia phragmitis:* the first stage of this plant appears in May or June upon the leaves and leaf-stalks of the ash; the spores formed in the yellow cluster-cups fall upon the leaves of the cord grass where they germinate, producing finally one-celled summer spores; later the same vegetative filaments produce black two-celled winter spores; draw a group of summer spores and winter spores; 1.

Why are the winter spores thick-walled? Where is the wall the thickest? Why? Explain the thin walls of the summer spores. Do you find any resemblance between the winter spore and an ascus with spores? (f. 113, p. 192.)

ORDER USTILAGINALES

FAMILY USTILAGINACEAE

27. *Ustilago maydis:* this plant occurs in great masses of spores in swollen, "smutted" ears of corn, rarely, when the fungus is developing, in masses of filaments, which produce spores internally at the tips; draw a group of spores; 2.

In what respects does this plant resemble Puccinia? (f. 115, p. 197.)

CLASS BASIDIOMYCETEAE

ORDER GASTEROMYCETALES

FAMILY LYCOPERDACEAE

28. *Lycoperdon gemmatum:* make a drawing of the puff-ball, which is really the spore fruit, and draw also some of the threads and spores of the interior; 2.

    Describe the puff-ball and its contents. How do the spores arise? Where does this plant grow? Is it a saprophyte? (f. 116, p. 199.)

ORDER HYMENOMYCETALES

FAMILY AGARICACEAE

29. *Agaricus campestris:* make a drawing of the entire spore fruit, also one showing the gill attachment in longitudinal section; cut a thin cross-section of the gills and draw a portion of one gill, showing the long central filaments or trama, the basidia and the spores; 1.

    Describe the structure of the mushroom in full. Compare the latter with the puff-ball. Compare the basidium and the ascus. Which is the higher form? Why? What is the vegetative body like? Where does it grow? (f. 118, p. 201.)

CLASS CHAROPHYCEAE

ORDER CHARALES

FAMILY CHARACEAE

30. *Nitella opaca:* draw a portion of a plant natural size, showing the habit and the branching; draw the upper part of a leaf, giving the detail of the

cells and the archegone and antherid; crush the latter and draw a cluster of the antherozoidal filaments; 1.

Describe the vegetative body in detail. Compare the archegone with the carpogone of Polysiphonia and the oogone of Oedogonium. Why is it higher? What is the structure of the antherid? Where do the stoneworts grow? (f. 120, p. 205: XXVII.)

BRANCH BRYOPHYTA.

Class Hepaticae

ORDER MARCHANTIALES

FAMILY MARCHANTIACEAE

31. *Marchantia polymorpha:* draw a portion of the thallus, showing the brood cups and the taller antheridial and archegonial branches; cut a section through brood cup and thallus and draw in detail; make vertical sections of the antheridial and archegonial disks; note the structure and draw an antherid and an archegone; crush a mature spore-bearing plant or sporophyte and draw several spores and elaters; 1.

Describe the structure of the thallus. Compare with it the wall of the brood-cup, and of the antheridial and archegonial disks. What does this show as to their origin? Contrast the stomata with those of flowering plants? What differences between the archegone and antherid of this plant and those of Nitella? What are the elaters for? Distinguish critically between the sexual plant or gametophyte and the spore-bearing plant or sporophyte. (f. 121, p. 208; f. 122, p. 209; f. 123, p. 210.)

CLASS MUSCINEAE

ORDER BRYALES

FAMILY PHYSCOMITRIACEAE

32. *Funaria hygrometrica:* draw a portion of the protonema, or young thread-like condition of the moss, showing the brown root-like filaments and the chlorophyll-bearing ones; draw the leafy plant, or gametophyte, bearing the fruiting plant, or sporophyte; draw the cluster of antherids and archegones, which usually occur separate at the tips of the gametophytes, along with the sterile threads or paraphyses; cut a longitudinal section of the capsule or sporophyte and draw the structure in detail.

Contrast the gametophytes of Marchantia and Funaria. Contrast the sporophytes. What kinds of tissues in the moss? Where do the mosses grow? Why? (f. 125, p. 213; f. 126, p. 214; f. 127, p. 216.)

BRANCH PTERIDOPHYTA.

CLASS EQUISETINEAE

ORDER EQUISETALES

FAMILY EQUISETACEAE

33. *Equisetum arvense:* draw a gametophyte or prothallium, showing if possible the antherids and archegones; make a drawing of the sterile and of

the fertile sporophyte, paying especial attention to the cone of the latter; draw also a portion of the cross-section of the cone, showing the shields and sporangia, and a spore showing the elaters. Describe the gametophyte and sporophyte in detail and compare them with the same structures among the Bryophyta. Where are the horse-tails found? Which appears first, the sterile or the fertile sporophyte? Which lasts the longer? (fs. 136, 137, p. 228.)

Class Filicineae

ORDER FILICALES

FAMILY POLYPODIACEAE

34. *Dryopteris marginata:* carefully remove the earth from the lower side of a prothallium by thorough washing, and mount the latter lower side up; draw the prothallium with its rhizoids, antherids, archegones; draw the leaf-like sporophyte, showing the fruit-dots or sori; draw a sporangium showing the spores.

Compare the prothallium with that of Equisetum. Describe the sporophyte and compare it with the sporophyte of the Bryophyta. What tissues do you find in ferns? Are normal stomata present on the gametophyte? on the sporophyte? Where are ferns found for the most part? Which generation is usually termed "fern," the gametophyte or the sporophyte? (f. 128, p. 220; f. 129, 130, p. 221; f. 133, p. 224.)

Class Lycopodineae

ORDER SELAGINELLALES

FAMILY SELAGINELLACEAE

35. *Selaginella rupestris:* draw a portion of the plant showing the fruiting cones; make a longitudinal section of the cone and draw it showing the sporophylls, microsporangia and macrosporangia.

Compare the sporophyte with that of the fern. What striking differences? What do these mean? Is the gametophyte present? What important differences from that of the fern? What differences in structure and function between the macrospores and microspores? Where does this plant grow? (f. 139, p. 233.)

BRANCH ANTHOPHYTA.

Class Gymnospermae

ORDER CONIFERAE

FAMILY PINACEAE

36. *Pinus austriaca:* draw a cluster of the microspore cones (staminate cones), and draw from an axial longitudinal section of a cone, showing the microsporophylls, microsporangia, and the microspores (pollen grains); draw also a microspore; draw a macrospore cone (pistillate) and part of a section of it, showing macrosporophyll, placental scale, and macrosporangium. During the last half of May, a section of the macrosporangium will usually show also the macrospore

(embryo sac) which has already germinated to form a prothallium, which remains always enclosed within the spore; at the tip of the prothallium (endosperm) may be found two or three elliptical hollows with necks, the archegones. Compare the pine tree, the sporophyte, with the sporophyte of Selaginella. What similarities and differences between the cones of the two plants? How does the prothallium of the pine differ from that of the fern? Contrast the relative size and importance of the gametophyte and sporophyte of the pine with the relative size and importance of the gametophyte and sporophyte of the liverwort, Marchantia. (fs. 141, 142, p. 240; f. 143, p. 241; f. 144, p. 243.)

CLASS ANGIOSPERMAE

SUBCLASS MONOCOTYLEDONEAE

ORDER CORONARIALES

FAMILY LILIACEAE

37. *Erythronium albidum* (Leucocrinum montanum, Tulipa gesneriana): make a sketch of the whole sporophyte; make an accurate drawing of the vertical section of the flower, showing the sterile sporophylls (petals and sepals), the microsporophylls (stamens) and the macrosporophylls (pistil) with the macrosporangia (ovules) inclosed; careful sections through the gynoecium will usually show the teguments of the macrosporangium and often the macrospore with its prothallium. (f. 211, p. 312.)

Describe the flower in full with especial reference to the number and position of the flower parts and fix it in mind as the type of the lily-like flowers, 323. Contrast the sporophyte and gametophyte with preceding ones. Where does this plant grow? Are there any indications of this in its structure?

ORDER GLUMALES

FAMILY GRAMINACEAE

38. *Poa pratensis:* make a sketch of the whole sporophyte; make a careful sketch of the spikelet, showing the microsporophylls and of a single floret, showing the macrosporophyll.
Contrast the floret with the flower of Erythronium, showing what modifications have occurred and what parts have been dropped out. In both the sedges and grasses, the petals and sepals are reduced to scales or bristles, or are lacking. The sedges, Cyperaceae, differ from the grasses in having the floret supported by a single scale in place of two.

SUBCLASS DICOTYLEDONES

ORDER THALAMIFLORALES

SUBORDER RANALES

FAMILY RANUNCULACEAE

39. *Ranunculus abortivus* (Anemone caroliniana, Pulsatilla hirsutissima): make a sketch of the sporophyte; make a drawing of the flower showing the arrangement of the parts. Cut a vertical section of the flower and note the position of

the different parts with reference to the receptacle.

What differences in the structure of the stem between Monocotyledons and Dicotyledons? What difference in the plan of the flower? What features of this flower indicate its low position in the line of development?

ORDER CALYCIFLORALES

SUBORDER ROSALES

FAMILY ROSACEAE

40. *Prunus americana:* draw a cluster of the flowers, and also the vertical section of a single flower, with especial reference to the position of the stamens and the cavity of the macrosporophyll. Describe the flower structure in full and compare it with that of Ranunculus. Why is it higher or more advanced than Ranunculus?

FAMILY PAPILIONACEAE

41. *Astragalus crassicarpus:* draw a portion of the plant showing the leaves and flower cluster; also a single flower in front and side view; remove the petals, noting their position and shape and draw the column of microsporophylls and the tip of the macrosporophyll. What is the pod like? Describe the flower structure in full? How does it differ from that of Prunus? Distinguish an actinomorphic from a zygomorphic flower? Which is the higher structure?

FAMILY SAXIFRAGACEAE

42. *Ribes gracile* (Ribes aureum): draw a flower cluster with leaves; also a single flower and a cross-section showing the structure of the macrosporophyll.
    Describe the flower and compare it with Astragalus and Prunus? Why is it higher?

ORDER BICARPELLALES

SUBORDER POLEMONIALES

FAMILY BORAGINACEAE

43. *Lithospermum angustifolium* (Lithospermum hirtum): make a careful sketch of the sporophyte; draw a single flower showing the calyx and corolla and also a vertical section with especial reference to the micro- and macrosporophylls.
    Describe the flower structure in full and compare it with that of Ranunculus.

ORDER INFERALES

SUBORDER RUBIALES

FAMILY RUBIACEAE

44. *Galium aparine:* make a sketch of the sporophyte; draw a single flower and also a fruit, the latter in cross-section.
    Describe the structure of the flower and compare it with that of Ribes.

SUBORDER ASTERALES

FAMILY COMPOSITAE

45. *Senecio plattensis:* sketch the sporophyte and draw a single flower cluster or head enlarged two

or three times; draw both a disk and a ray floret enlarged several times.

Describe the structure of the head and of both sorts of florets. Compare the latter with the flowers of Galium. What has become of the calyx? What is the purpose of the pappus?

46. *Taraxacum taraxacum* (Nothocalais cuspidata): draw a head in front view and also in vertical section; draw a floret from the edge and from the center of the disk.

Compare the structure of the head with that of Senecio. Compare the florets of both also. Contrast in detail Ranunculus with Taraxacum in regard to flower structure. Point out all the particulars in which the latter is the higher.

PHYTOGEOGRAPHY

Select a readily accessible portion of the vicinity, which manifests a large degree of diversity in the vegetative covering. Draw a map of this area on the scale of ten inches to the mile, showing section lines, roads, streams, ponds, swamps, hills, etc. Indicate provisionally the areas covered by the different sorts of vegetation, woodland, meadow, swamp, pond, weed patches, cultivated fields, groves, orchards, etc.

Identify the flowers in each formation as they appear in the spring. Where there is not sufficient time to work them all, determine the most important or abundant. It will soon be seen that, while trees are the characteristic plants of woodlands, grasses of meadows and prairies, etc., other plants are especially typical of such formations on account of their abundance or prominence. These are the principal species of the formation, while the less abundant or less important ones are secondary species. Determine for those formations which are early enough the fundamental species or facies, the principal species, and as many of the secondary species as possible. List the species of each formation, arranging the facies, principal species, etc., according to the time of their flowering. (Chapter V. Phytogeography of Nebraska.)

Determine which areas of the locality studied are hydrophytic, which mesophytic, and which xerophytic. Point out which physical factors are at work in all of them, influencing the vegetation which grows there, and in what way certain of these factors differ in the different situations. Note what structural modifications are common to each group, and try to connect these with the physical conditions peculiar to the situation. Note that the mesophytes may be woodland plants, grassland plants, or weeds. Make a list of hydrophytes, hylophytes, poophytes, cledophytes, and xerophytes, arranging them in so far as possible according to the degree to which they have become modified in response to the controlling conditions in their environment. (Chapter IV.)

Arrange the species of each formation according to their vegetation form, and point out the connection between the typical structure, which determines the vegetation form, and the habitat. (Chapter III.)

Indicate upon the topographical map the various plant formations of the vegetative covering either by shading with conventional signs or, better, by colors. Transition areas in which two formations mingle may be indicated by mingling both signs, or by using a shade intermediate between the two colors. A neat legend should be attached, giving the name and facies of each formation opposite its sign or color.

SYNOPSIS OF THE LARGER GROUPS OF THE VEGETABLE KINGDOM

BRANCH I.—Protophyta. Protophytes
Water Slimes

Class.—Schizophyceae. Fission Algae

ORDER.—Cystiphoreae.
Fam.—Chroococcoceae. Gloeocapsa arenaria.

ORDER.—Nematogeneae.
Fam.—Nostocaceae. Nostoc commune.
Fam.—Oscillatoriaceae. Oscillatoria tenuis.
Fam.—Scytonemataceae. Scytonema cinereum.
Fam.—Rivulariaceae. Gloeotrichia pisum.
Fam.—Bacteriaceae. Bacillus subtilis. Spirillum undula.

BRANCH II.—Phycophyta. Phycophytes
Spore Tangles

Class.—Chlorophyceae. Green Algae

ORDER.—Protococcoideae.
Fam.—Pleurococcaceae. Protococcus viridis, Scenedesmus obliquus.

ORDER.—Conjugatae.
Fam.—Desmidiaceae. Closterium lanceolatum.
Fam.—Bacillariaceae. Navicula viridis.
Fam.—Zygnemaceae. Spirogyra nitida.
Fam.—Mucoraceae. Ascophora mucedo.

ORDER.—Siphoneae.

Fam.—Vaucheriaceae. Vaucheria hamata.

Fam.—Peronosporaceae. Peronospora parasitica.

ORDER.—Confervoideae.

Fam.—Ulotrichiaceae. Microspora abbreviata.

Fam.—Oedogoniaceae. Oedogonium nodulosum.

Class.—Phaeophyceae. Brown Algae

ORDER.—Phaeosporeae.

Fam.—Ectocarpaceae. Ectocarpus litoralis.

ORDER.—Fucoideae.

Fam.—Fucaceae. Fucus fastigiatus.

BRANCH III.—Carpophyta. Carpophytes
Fruit Tangles

Class.—Rhodophyceae. Red Seaweeds

ORDER—Florideae.

Fam.—Rhodomelaceae. Polysiphonia fastigiata.

Class.—Ascomycetes. Sac-Fungi

ORDER.—Perisporiaceae. Simple Sac-Fungi.

Fam.—Erysipheae. Uncinula salicis.

ORDER.—Tuberales.

Fam.—Tuberaceae. Tuber melanosporum.

ORDER.—Pyrenomycetales. Black Fungi.

Fam.—Hysteriaceae. Hysterographium fraxini.

ORDER.—Discomycetales. Cup Fungi.

Fam.—Pezizaceae. Sepultaria scutellata.

Fam.—Parmeliaceae. Physcia stellaris.

ORDER.—Uredinales. Rusts.
Fam.—Uredinaceae. Puccinia phragmitis.

ORDER.—Ustilaginales. Smuts.
Fam.—Ustilaginaceae. Ustilago maydis.

Class.—Basidiomycetaceae. Higher Fungi

ORDER.—Gasteromycetales. Puff-balls, etc.
Fam.—Lycoperdaceae. Lycoperdon gemmatum.

ORDER.—Hymenomycetales. Toadstools, etc.
Fam.—Agaricaceae. Agaricus campestris.

Class.—Charophyceae. Stoneworts

ORDER.—Charales.
Fam.—Characeae. Nitella opaca.

BRANCH IV.—Bryophyta. Bryophytes
Mossworts

Class.—Hepaticae. Liverworts

ORDER.—Marchantiales.
Fam.—Marchantiaceae. Marchantia polymorpha.

Class.—Muscineae. Mosses

ORDER.—Bryales.
Fam.—Physcomitriaceae. Funaria hygrometrica.

BRANCH V.—Pteridophyta. Pteridophytes
Fernworts

Class.—Equisetineae. Joint Rushes

ORDER.—Equisetales.

Fam.—Equisetaceae. Equisetum arvense.

Class.—Filicineae. Ferns

ORDER.—Filicales. True Ferns.

Fam.—Polypodiaceae. Dryopteris marginata.

Class.—Lycopodineae. Lycopods

ORDER.—Selaginellales. Little Club-mosses.

Fam.—Selaginellaceae. Selaginella rupestris.

BRANCH VI.—Anthophyta. Anthophytes
Flowering Plants

Class.—Gymnospermae. Gymnosperms

ORDER.—Coniferae. Conifers.

Fam.—Pinaceae. Pinus austriaca.

Class.—Angiospermae. Angiosperms

Subclass.—Monocotyledones. Monocotyledons

ORDER.—Coronariales. Lilies.

Fam.—Liliaceae. Erythronium albidum.

ORDER.—Glumales. Grasses.

Fam.—Graminaceae. Poa pratensis.

Subclass.—Dicotyledones. Dicotyledons

ORDER.—Thalamiflorales. Torals.

SUB-ORDER.—Ranales.

Fam.—Ranunculaceae. Ranunculus abortivus.

ORDER.—Calyciflorales. Calycals.

SUB-ORDER.—Rosales.

Fam.—Rosaceae. Prunus americana.

Fam.—Papilionaceae. Astragalus crassicarpus.
Fam.—Saxifragaceae. Ribes gracile.

ORDER.—Bicarpellales.
SUB-ORDER.—Polemoniales.
Fam.—Boraginaceae. Lithospermum angustifolium.

ORDER.—Inferales.
SUB-ORDER.—Rubiales.
Fam.—Rubiaceae. Galium aparine.
SUB-ORDER.—Asterales.
Fam.—Compositae.—Senecio plattensis. Taraxacum taraxacum.

PHYSIOLOGY

Experiment 1

Germinate several seeds—corn, beans, peas—by placing same between folds of *moist blotting* paper. *Or,* place the seeds on cotton screen cloth, covering the top of a wide-mouthed bottle. This will allow the water in the bottle to just come into contact with seeds. The whole may be covered with a bell jar or left exposed to ordinary air of a room. Temperature 21° to 23° C. The apparatus thus described may be called *the germinator.*

Experiment 2

Prepare the following—Nutrient Solution or Culture Solution:

Distilled water (H_2O)	1000 cc.
Potassium nitrate (KNO_3)	1 gram
Magnesium sulphate ($MgSO_4$)	0.5 gram
Calcium sulphate ($CaSO_4$)	0.5 gram
Calcium phosphate $Ca_3(PO_4)_2$	0.5 gram

Add to this a trace of some iron salt, Fe_2Cl_6 (Ferric chlorid) or $FeSO_4$ (Ferrous sulphate). Keep solution in dark. Aerate occasionally during culture experiment.

Experiment 3

Fill beaker or jar with *nutrient solution*. Cover with cork or pasteboard which has been slit; through opening pass roots, or slip of some plant. Arrange another beaker or jar similarly, except fill with *distilled water* instead of nutrient solution. Observe growth of two slips or plants from day to day.

Experiment with seedlings—Are results similar?

Experiment 4

Grow sets of seedlings under the four following conditions:

(a) Distilled water.

(b) Nutrient solution (without iron).

(c) Nutrient solution (with iron).

(d) In soil.

Compare results. Do not repeat *(a)* and *(c)* if previously performed.

Experiment 5.—Absorption of Minerals Which are Insoluble in H_2O

(a) Take seedlings grown in germinator and touch the moist root-tips to blue litmus paper.

The paper becomes red in color showing presence of acids in the root-tip.

This acid will dissolve certain constituents of soil which are *insoluble in* H_2O.

(b) Grow a seedling in soil previously placed on a *polished bit of marble*. After a few weeks wash off and examine for "root tracks." Acid of roots will have eaten fine tracks into surface of marble.

Experiment 6.—Absorption

Place leaves of different varieties, in 5 per cent solution of common salt. The entire blade should be immersed, but the petioles should project out of the solution. Arrange two sets of leaves; one in salt solution, the other in pure water. After several hours examine. Which are normal and which have lost their turgidity?

Experiment 7

Cut several pieces of beet of equal size and about 5 mm. in thickness. Immerse a few slices each, in water, in salt solution, and in sugar solution. At first slices will be rigid. After one or two hours examine slices. Notice difference in rigidity. Why is this? Which solution has the greatest softening effect? Explain. Wash the slices in salt solution and place in dish of pure water. Examine after a few hours. What effect? Explain.

Experiment 8

To some cells of Spirogyra under microscope add a little KOH (Potassium hydrate). Potassium hydrate induces in the cell the power of imbibing water to greater extent than ordinarily.

Try same with H_2SO_4 (Sulphuric acid). Note results.

Try same with 5 per cent solution of common salt (NaCl). After 5 minutes, flow pure water under the cover glass and again notice effect.

Experiment 9.—Water from Soil

Examine under *low power* of microscope some fine root hairs of corn seedlings *grown in earth.* Fine particles of earth will be seen clinging to root hairs. Plants take water from soil which is merely moist.

Experiment 10.—The Ascending Current

Evaporate on a cover glass, a little H_2O obtained by cutting stem of some herbaceous plant. Is the H_2O pure? Heat the residue. Does it carbonize? *What does this indicate* about the *so-called sap?*

Experiment 11

Determine percentage of water in grass, clover, etc. Weigh accurately a small bunch of grass—about a handful. Dry for twenty-four hours in drying oven. *Reweigh* and determine *actual loss* of weight. *Percentage of loss?*

Experiment 12

Cut near the ground a stem of sunflower, dahlia, Indian corn, or any strongly growing herbaceous plant. Dry cut end with blotting paper and then examine with hand lens. Where do you notice H_2O? Is it exuding from *cut ends* of *fibrovascular bundles?* How much water would escape in this way in one day? Estimate.

Look up fibrovascular bundles in Bessey or Bergen.

Experiment 13

Place the freshly cut ends of sunflower shoots, corn stems, Impatiens or Caladium in a solution of eosin, fuchsin, or red ink. After a few hours make cross-sections of the various stems and examine for the *red areas.* How are they arranged? Cut longitudinally through one of these areas. Try various kinds of stems. Examine a cross-section of one of the stems with the microscope, low power. Are the red areas of especially constructed cells? What are the fibro-vascular bundles?

EXPERIMENT 14

(To be performed in spring or fall when leafy twigs or branches are abundant).

Take a branch of woody plant—remove bark entirely from stem for ½-inch. Place in H_2O and notice leaves both above and below the injury. Is there a perceptible difference in freshness?

With another twig remove ½-inch of wood without injuring bark more than necessary. Compare leaves above and below the injury when the twig is placed in H_2O.

EXPERIMENT 15.—TRANSPIRATION

Study morphology of Stomata on leaves. Can you conclude that leaves are special organs of transpiration?

Exp. Weigh a plant. Then allow a period of rapid evaporation from leaves (covering mouth of pot with sheet rubber). Reweigh after the period and note difference.

Experiment 16

Fit the stem of a growing shoot into end of glass tube by means of a cork. Fill tube with H_2O and place bottom end in beaker of *colored water* or mercury. The transpiring shoot produces what results?

Experiment 17

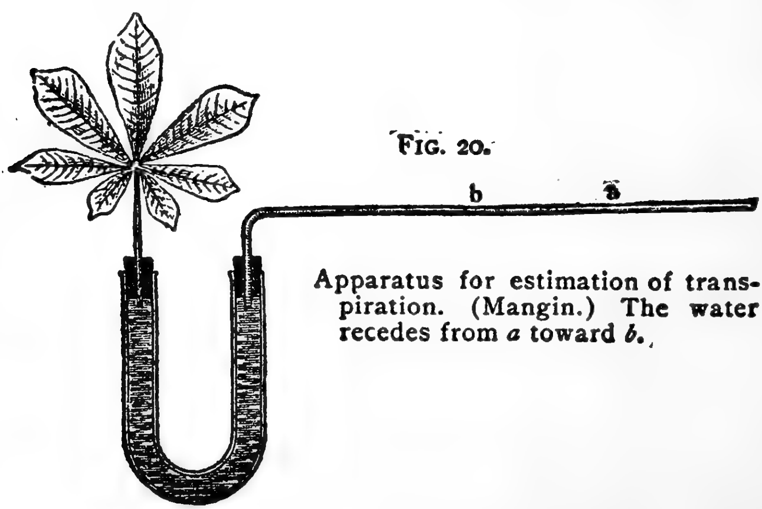
Take two geranium leaves, varnish one on both sides. Place side by side on table in laboratory. What effect? Which wilts? What have you preserved by varnishing the one leaf?

Experiment 18

Fit a growing shoot through a cork into one arm of a U tube. Fill tube with water. From the other arm of the tube lead out a $\frac{1}{8}$-inch glass tube horizontally. This should contain water, and its flow towards the arm can be noted as indicative of amount of transpiration.

Cf. MacDougal's "Plant Physiology," p. 23.

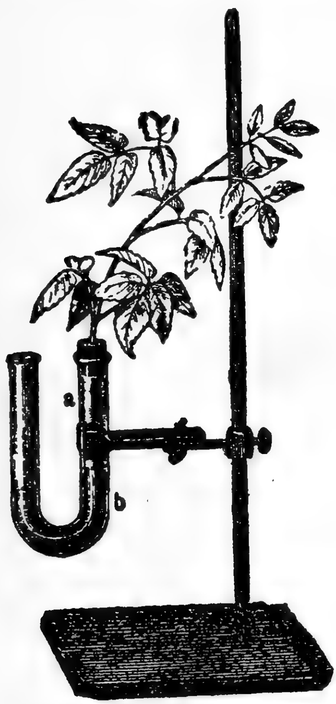
FIG. 20.



Apparatus for estimation of transpiration. (Mangin.) The water recedes from *a* toward *b*.

EXPERIMENT 19.—LIVING PLANTS ABLE TO CONTROL TRANSPIRATION

Take two sprigs of clover, immerse one in boiling water to kill it, and immerse the other in cold water so that the leaves are well wetted. *Lay both plants* on table and notice results in drying. Which is surface-dry the sooner? Which entirely dry? Did living plant hold moisture longer than dead plant?



Lifting power of transpiration. (After Oels.) *a*, water; *b*, mercury.

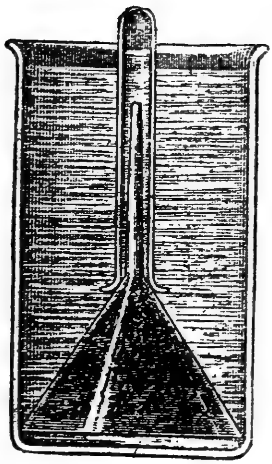
EXPERIMENT 20

Fit a growing shoot into a cork, which when placed in one end of a "U" tube will render the whole water-tight. Fill this end of the tube with water; insert the cork. Pour mercury into other arm of tube until it stands one inch high in both arms. After a time the mercury will rise in the first arm. Why? Does this indicate lifting power?

EXPERIMENT 21

Take several leaves, geranium and others, and place their petioles in long pill bottles containing H_2O, closing the mouth of the bottle with softened wax or paraffin. Notice level of water in bottles after 12 hours; after 24 hours, etc. Weigh these bottles at intervals of 6 hours. Record results. Conclusions?

EXPERIMENT 22.—METABOLISM



Cover some water plants or green algae, in a glass jar, with a funnel filled with water. Invert a test tube filled with H_2O over this funnel, so that mouth of tube is beneath surface of water in jar. Bubbles rising from growing plants will collect in tube displacing H_2O. What are they? When tube is filled, place thumb over the opening and remove. Insert a lighted taper. Conclusions? Note reaction given with Experiment 25.

EXPERIMENT 23

Cylinder containing germinating Peas. (Sachs.)

Take a handful of peas and soak in warm water for 12 hours or in cold water for 24 hours. Drain off water and place peas in tall glass cylinder. Cover the top as nearly *air tight* as possible and set aside for 12 hours. Now remove the cover slightly and lower lighted taper into jar. If it is extinguished, it indicates a lack of oxygen. Lower spoonful of lime water. If the surface becomes covered with a film this indicates carbon dioxid (CO_2). Your conclusions? Peas in germination *absorb what? Give off what?*

Experiment 24

Parasitic plants (fungi) have no chlorophyll. They do not make their own starch, nor assimilate CO_2. Examine under microscope the Dodder, for chlorophyll grains. Examine in like manner various fungi, as molds. Examine green leaves, under microscope, for chlorophyll.

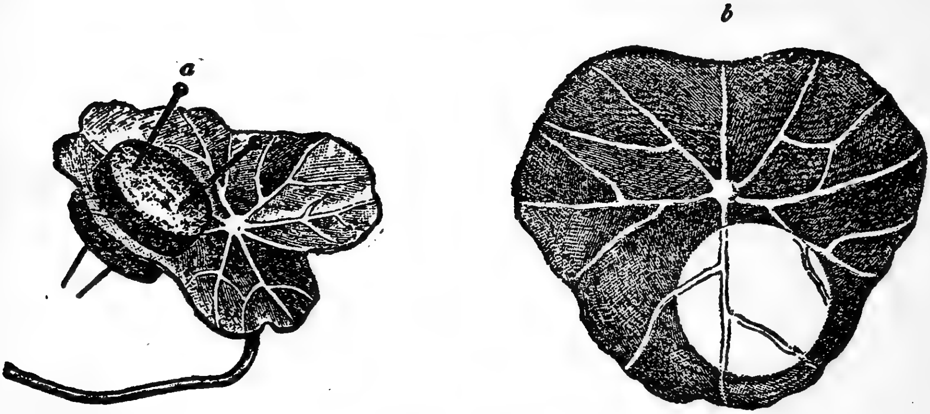
Experiment 25.—Assimilation

Burn a match. What is the resulting charred stick? Whence do plants derive this carbon? Is carbon present in air? In what form? *Note carefully* $6CO_2+5H_2O=\underbrace{C_6H_{10}O_5}_{\text{Starch}}+6O_2$.

Experiment 26.—Schimper's Method of testing for Presence of Starch

A strong solution of chloral hydrate is made by taking 8 grams of chloral hydrate for every 5 cc. of water. To this solution is added a little of an alcoholic tincture of iodin.

Threads of Spirogyra may be placed in this solution and in few minutes examined under microscope. The reaction will be distinctly seen.



a, Tropæolum leaf to which are attached two pieces of cork to prevent photosynthesis. (Detmer.) *b*, same after removal of cork, treated with iodin.

EXPERIMENT 27

Cover a portion of a growing leaf with cork, as per figure. After some days, pluck leaf, remove cork, and immerse leaf in solution of iodin. What color is the strip covered by cork—before and after immersion. A blue color would indicate starch. Explain results.

EXPERIMENT 28

To two ounces of ground flaxseed add about 2 ozs. of ether. Allow to stand for 15 or 20 minutes and then allow ether to evaporate in draught. What remains? Where did it come from? Is starch the only product of plant activity? Name other products?

Experiment 29.—Heat in Germination

Apparatus to demonstrate liberation of heat in respiration. (Sachs.)

Fill a beaker $\frac{1}{4}$ full with strong solution of KOH (Potassium hydrate). Into this place a funnel filled with soaked peas, taking care that the funnel does not come into contact with solution of KOH. A thermometer is inserted into the mass of peas, the whole covered by bell jar. The KOH is used to absorb what gas given off in germination? Compare temperature as indicated by thermometer in peas with temperature of outside air.

Experiment 30

Place dry beans or peas in a temperature of about 70° C. for 15 minutes. They will not be killed. Now *thoroughly soak* a few beans, and subject them to the *same temperature* for about the same length of time. Attempt to grow them after removal from oven. Will they grow? Conclusions.

Experiment 31.—Growth—To Mark Radicles With Ink

Mount a few inches of fine thread in a needle holder. Allow insoluble India ink to soak into thread which has been stretched. By holding this inked thread taut and pressing down on the roots, a fine, even line may be obtained.

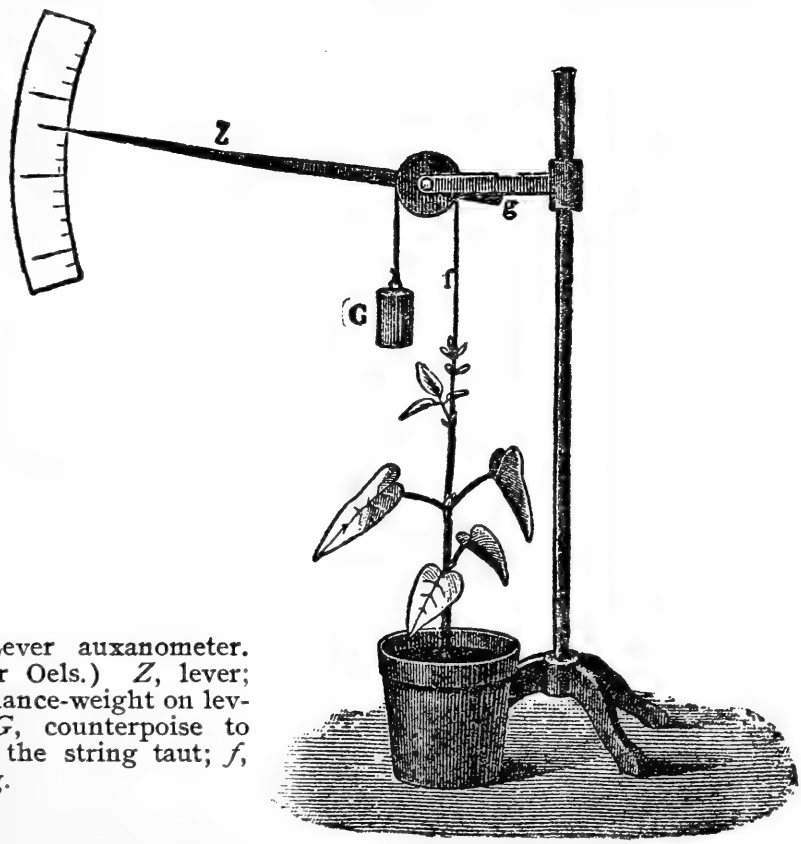
Experiment 32

Germinate a bean, and when root-tip is about one inch in length, mark with India ink on the tip ten millimeter divisions. Allow seedling to remain in culture 24 hours. Then re-examine. Notice position of millimeter marks. Transfer results accurately to plotting paper. Scale 1-5. Notice carefully increase in each zone. *Try with various seedlings.*

Seedling of Pea. (Sachs.) Showing zone of maximum growth.

Experiment 33.—To Measure Growth in Length of Plant

Auxanometer.—The thread fastened to top of plant to be observed is passed over a movable pulley, and held taut by a weight, which should not be so heavy as to strain the plant. To pulley is attached a slender pointer which is 20 times as long as the radius of the pulley, indicating growth 20 fold. Arrange so that pointer may indicate on a scale or that pointer may touch a clean sheet of paper which may be marked. Measure growth of potato plant or lily grown in a pot or box. Compare day growth with night growth.



Lever auxanometer. (After Oels.) *Z*, lever; *g*, balance-weight on lever; *G*, counterpoise to keep the string taut; *f*, string.

Experiment 34

Fix pots containing growing shoots in unusual positions about the room. Observe carefully any change of direction taken by the growing parts of the plant.

Experiment 35

Sprout a lima bean and allow to grow in one position until lateral roots are 15 to 20 cm. in length. Now invert, and allow to remain for 24 hours, or longer. Return to normal position and notice effect a day after the inversion. Draw the curve of the rootlets.

Experiment 36

Arrange some bean seedlings around a disc of cork which can be rapidly rotated. Notice after a few hours the effect of centrifugal force upon rootlets. Has the centrifugal force overcome that of gravity? What is geotropism?

Experiment 37.—Irritability—Contact, Light, etc.

Obtain a cracker box and give the inside, including inside of cover, a coat of black paint. Nail cleats across boards of cover that it may be removed easily. Now cut an opening 3 inches in diameter in one end and attach a cylinder about 6 inches in length. When completed the affair will resemble a camera box. When cover is on, the cylinder opening should be the only place where light may enter.

Experiment with various plants, allowing them to remain in the box various lengths of time. Two days on the average is a good length of time. Note the tendency of the growing shoots to seek the light. Arrange a set of "stops" for the opening of the box, and experiment with reduced light. Do the growing plants bend toward the light?

Experiment 38

Grow a "nasturtium" (Tropaeolum) in a window. Note the positions taken by the leaves with respect to the light.

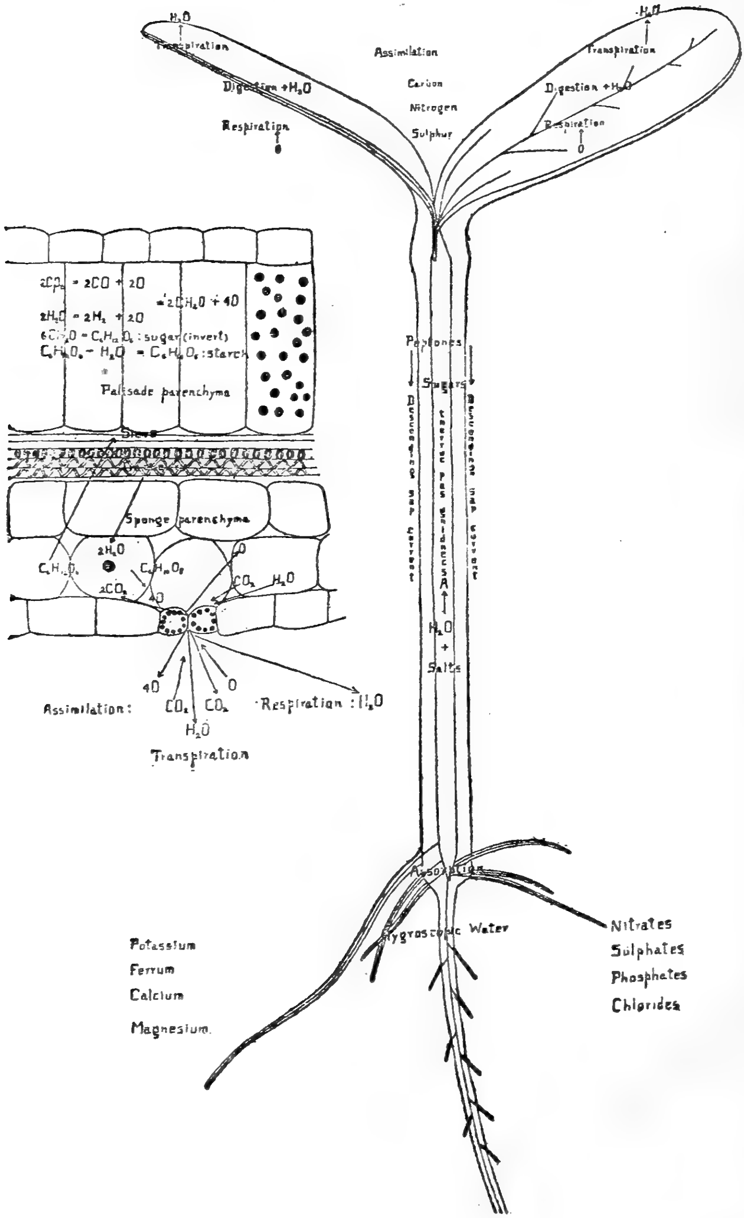
Experiment 39

All laboratories should have a sensitive plant. Mimosa pudica may be obtained from a florist.

Cause temperature to rise around the plant. Notice loss of irritability. Cause temperature to fall. What result?

Allow plant to dry. What result? Add water. What result? Note carefully irritability due to contact.

ABSORPTION, TRANSFER, AND NUTRITION IN THE PLANT.



APPENDIX

REMARKS

1. Give the experiments which require much preparation to various pupils at the beginning of the course.

2. An effort has been put forth to make the glossary very complete. *Refer constantly* to this, and thus become *familiar* with *terms* employed.

3. In the part of the Manual devoted to physiology, use especially MacDougal, Bessey, and Bergen for reference.

4. It is urged upon the smaller high schools of the state that a *beginning* in *laboratory botany* is most essential, *no matter* how insignificant that beginning may be. The course outlined in the Manual is complete enough for the best equipped school in the state, and it is not intended that the high school carrying a light equipment shall attempt the complete course.

5. It is further urged that the laboratory "quiz" method of instruction be largely employed. Let the teacher, instead of "lecturing" two or three times per week, go into the laboratory, and there "quiz" the pupils upon work *actually in hand*, at the same time *bringing out related matters* from the text-book lesson. *Converse freely* with the *students* about the experiments or class work.

6. Attention is called to the outline of the vegetable kingdom—prepared by Dr. Bessey.

7. Correspondence regarding the needs of your course in Botany is invited by the Department of Botany, The University of Nebraska, Lincoln. Upon request doubtful plants will be named or verified.

GLOSSARY

Abbreviata: L. abbreviatus, shortened.

Abortivus: L. abortivus, abortive.

Abundance: the quantity of a species measured by the number of individuals.

-aceae: L. -aceus, pertaining to.

Actinomorphic: Gr. ἀκτῖς, aktis, ἀκτῖνος, aktinos, ray; μορφή, morphe, form, radially symmetrical, as the flower of the rose.

Adventitious: L. adventitius, strange, belonging to a remote vegetation, foreign.

Agaricaceae: L. agaricus, mushroom.

Agave: Gr. ἀγαυός, agauos, noble, a genus of the Amaryllis family.

Aianthous: Gr. αἰών, aion, age, ἄνθος, anthos, flower, continuing in bloom throughout the season.

Albidum: L. albidus, white.

-ales: L. alis, pertaining to.

Aleurone: Gr. ἄλευρον, aleuron, fine meal, fine granules of albuminoid or proteid found in seeds.

Algae: L. alga, seaweed, the term applied to the green aquatic forms of the first three branches.

Allogamy: Gr. ἄλλος, allos, another, γάμος, gamos, marriage, the fertilization of the pistil of one flower by the pollen or microspores of another; cross-fertilization.

Americana: L. americanus, American.

Androecium: Gr. ἀνήρ, aner, ἀνδρός, andros, man, οἰκίον, oikion, house, the microsporophylls or stamens taken collectively.

Anemone: Gr. ἄνεμος, anemos, wind.

Angiospermae: Gr. ἄγγιον, angion, vessel, σπέρμα, sperma, seed.

Angustifolium: L. angustus, narrow, folium, leaf.

Antherid: Gr. ἀνθερίδιον, antheridion, blooming, the male organ, from Phycophyta to Pteridophyta, producing the antherozoids.

Antherozoid: Gr. ἄνθος, anthos, flower, ζῶον zoon, animal, εἶδος, eidos, shape, the fertilizing body produced in the antherid.

Apical cell: the tip cell of a filament or tissue, by the division of which growth is effected.

Apothecium: Gr. ἀπό, apo, away, θήκη, theke, case, box, the disk or cup-like spore-fruit of cup-fungi and lichens in which the hymenium is exposed.

Appendage: the filament developed as a holdfast upon the perithecium of the Erysiphaceae.

Aquilina: L. aquilinus, pertaining to an eagle or standard.

Archegone: Gr. ἀρχή, arche, first, γονίον, gonion, offspring, the female reproductive organ of ferns and flowering plants.

Arenaria: L. arenarius, sandy.

Areole: L. dim. of area, ground, a small clear space, around the nucleolus.

Asclepias: Gr. Ασκληπιός, Asklepios, the Greek god of medicine, a genus of the Asclepiadaceae.

Ascomycetales: Gr. ἀσκός, askos, sack, μύκης, mykes, mushroom.

Ascophora: Gr. ἀσκός, askos, sack, φορά, phora, bear.

Ascus: Gr. ἀσκός, askos, sack, the spore sack of the Ascomycetes.

Aspect: the tone or appearance of a formation during a particular period.

Asterales: Gr. ἀστήρ, aster, a star.

Astragalus: Gr. ἀστήρ, aster, a star, γάλα, gala, milk.

Aureum: L. aureus, golden.

Austriaca: L. austriacus, southern.

Autogamy: Gr. αὐτός, autos, self, γάμος, gamos, marriage, fertilization of a pistil by pollen of the same flower; self-fertilization.

Bacillaria: L. baculus, rod.

Bacillus: L. baculus, rod.

Bacterium: Gr. βακτήριον, bakterion, staff, a one-celled Protophyte, either parasitic or saprophytic.

Balsamina: L. balsaminus, balsamic.

Basidiomycetes: Gr. βασίδιον, basidion, pedicel, μύκης, mykes, mushroom.

Basidium: Gr. βασίδιον, basidion, a little base, the swollen tip of a filament upon which the spores are borne in the puff-balls and mushrooms.

Bast fibre; a long, thick-walled, usually lignified fiber, belonging to the sieve portion of the fibrovascular bundle.

Begonia: named for Begon, an early governor of St. Domingo, a genus of Begoniaceae.

Bergamot: (name of Italian town, Bergamo), the oil of the bergamot orange (Citrus medica).

Beta: L. beta, beet, a genus of Chenopodiaceae.

Bilateral: L. bi, two, latus, side, two-sided, in two directions.

Bicarpellales: L. bi, two, carpus, fruit.

Boraginaceae: ancient Latin name.

Branch: a primary group of the vegetable kingdom, as Protophyta.

Breathing pores: the openings through the epidermis into the soft tissue, by which gases are absorbed and given off.

Bristle: a stiff hair, especially those of the sedge flower.

Brood cups: the structures produced upon the thallus of liverworts, bearing buds or gemmae.

Bryophyta: Gr. βρύον, bryon, moss, φυτόν, phyton, plant.

Bryum: Gr. βρύον, bryon, moss.

Bundle: a union of sieve and tracheary tissues to form supportive fibres or columns.

Callose: L. callosus, hard, a substance resembling cellulose, occurring upon the sieve plates during the resting period.

Calyciflorales: Gr. κάλυξ, kalyx, cup, L. flos, flower.

Calyx: Gr. κάλυξ, kalyx, cup of a flower, the outer row of sterile sporophylls, called sepals.

Cambium: L.L. cambium, exchange, the zone of meristematic tissue which causes the growth in thickness of stems and roots.

Campestris: L. campestris, of the field.

Canadensis: L. canadensis, Canadian.

Capsule: L. capsula, from Gr. κάψα, kapsa, chest, the spore-bearing structure of mosses; also the pod of certain flowering plants, lily, etc.

Carpogone: Gr. καρπός, karpos, fruit, γονίον, gonion, offspring, the female reproductive organ of the red seaweeds, etc.

Carpophyta: Gr: καρπός, karpos, fruit, φυτόν, phyton, plant.

Cell: L. cella, cell, the plant unit, consisting usually of a wall, protoplasm and nucleus.

Cellulose: L. cellula, little cell, the substance resembling starch, making up the walls of the cells of soft tissue.

Centrifugal: L. centrum, center, fugere, to flee from.

Centrifugal force: that force by which a body in revolution or rotation tends to fly off from the center.

Cerevisiae: L. cerevisia, beer, belonging to beer.

Chara: Gr. χαρά, chara, joy.

Charophyceae: Gr. χαρά, chara, joy, φύκος, phykos, seaweed.

Chlorophyceae: Gr. χλωρός, chloros, green, φύκος, phykos, seaweed.

Chlorophyll: Gr. χλωρός, chloros, grass-green, φύλλον, phyllon, leaf, the yellow green coloring matter of plants, especially of leaves.

Chloroplast: Gr. χλωρός, chloros, green, πλαστός, plastos, formed, a bit of protoplasm stained green with chlorophyll.

Chromatophore: Gr. χρῶμα, chroma, color, φορά, phora, bearing, a definite mass of protoplasm producing a pigment.

Chromoplast: Gr. χρῶμα chroma, color, πλαστός, plastos, formed, a bit of protoplasm colored by a red or yellow pigment.

Chroococcaceae: Gr. χρῶς, chroos, color, κόκκος, kokkos, berry.

Cinereum: L. cinereus, ashy, gray.

Class: a group of plants next below a branch in rank, as Schizophyceae.

Closed bundle: a collateral bundle having no cambium and hence incapable of further growth, as in corn.

Closterium: Gr. κλωστήριον, klosterion, small thread or line.

Cluster cup: a cup-like structure in which the spring spores or aecidiospores of the rusts are produced.

Collateral bundle: the kind of fibrovascular bundle in which the xylem and phloem are side by side, the former inside, the latter outside.

Collenchyma: Gr. κόλλα, kolla, glue, ἐν, en, in, χυμός, chymos, juice, soft tissue in which the cells are usually elongated and reinforced by cellulose thickenings at the corners.

Colony: L. colonia, colony, a more or less definite group of one-celled plants.

Communis: L. communis, common.

Companion cell: an elongated cell associated with a sieve tube.

Compositae: L. compositus, compound.

Concentric: having a common center.

Conceptacle: L. conceptaculum, the pitlike cavity of certain brown seaweeds in which the sexual organs are formed.

Conductive: permitting or aiding the migration of plants.

Cone: an elongated axis bearing rows of microsporophylls or macrosporophylls, as in the pines.

Conferva: L. river sponge.

Conidia: Gr. κόνις, konis, dust, the propagative bodies in fungi, borne on special stalks or conidiophores.

Conidiophore: Gr. κονίδιον, konidion, spore, φορά, phora, carrying, a special branch or stalk on which spores are borne.

Coniferae: L. conus, cone, fero, bear.

Conjugation: L. con, with, jugum, yoke, the fusion of two sexual bodies.

Cork: a peculiar parenchyma-like tissue in which the cellulose is changed to suberin.

Corolla: L. corona, crown, the inner row of sterile sporophylls, or petals, of the flower.

Coronariales: L. corona, crown.

Crassicarpus: L. crassus, thick, carpus, fruit.

Cucurbita: L. cucurbita, gourd, a genus of Cucurbitaceae.

Cuspidata: L. cuspidatus, sharp.

Cuticle: L. skin, the outer wall of the epidermal cells, usually thickened in xerophytes.

Cyperaceae: Gr. κύπειρος, kypeirus, marsh plant.

Cystiphoreae: Gr. κύστις, kystis, sack, φορά, phora, carrying.

Cystocarp: Gr. κύστις, kystis, sack, καρπός, karpos, fruit, the fruit of the red seaweeds, arising from fertilization of the carpogone.

Cytoplasm: Gr. κύτος, kytos, jar, πλάσμα, plasma, form, the protoplasm of the cell.

Dehydration: the removal of water from specimens.

Deltoides: L. deltoides, delta-like or triangular.

Derived: proceeding from a contiguous vegetation.

Desmidium: Gr. δεσμίδιον, desmidion, little band.

Diaphragm: Gr. διά, dia, across, φράγμα, phragma, fence, the thin layer of cells stretching across the intercellular spaces of aquatic plants.

Dicotyledones: Gr. δί, di, double, κοτυληδών, kotyledon, vessel.

Discomycetales: Gr. δίσκος, diskos, disk, round plate, μύκης, mykes, mushroom.

Disk: the fruiting surface or hymenium of an apothecium; the central portion of a composite flower, the head, covered with tubular florets.

Distribution: the position and occurrence of a plant or formation in the vegetative covering.

District: the division of the vegetative covering next below the region in rank.

Dwarf male: a small, club-shaped body, of Oedogoniaceae, consisting of a stalk cell, and one or two antheridial cells.

-eae: L. eus, related to.

Ecology: Gr. οἶκος, oikos, house, λόγος, logos, science, the branch of botany which treats of the relation of plant and habitat.

Ectocarpus: Gr. ἐκτός, ektos, outside, καρπός, karpos, fruit.

Elater: Gr. ἐλατήρ, elater, charioteer, spiral thread or membranous band used in dispersing the spores in liverworts and horsetails.

Embryo sac: the full-grown macrospore of the macrosporangium of Anthophytes.

Endemic: Gr. ἐν, en, in, δήμιος, demios, belonging to the people, native.

Endosperm: Gr. ἔνδος, endos, within, σπέρμα, sperma, seed, the nutritious dependent prothallium of the macrospore of of Anthophytes.

Ephemeral: Gr. ἐπί, epi, upon, ἡμέρα, hemera, day, blooming for a single day.

Epidermal system: the outer layer or epidermis with all its modifications, hairs, stomata, etc.

Epidermis: Gr. ἐπί, epi, upon, δέρμα, derma, skin, the outer layer of cells of tissue-forming plants, ferns and flowering plants.

Equisetum: L. equus, horse, seta, bristle.

Erysiphe: Gr. ἐρυσίβη, erysibe, rust.

Erythronium: Gr. ἐρυθρός, erythros, red.

Esculentum: L. esculentus, esculent, edible.

Estival: L. aestivalis, pertaining to summer

Euphorbia: Gr. εὐφόρβιον, euphorbion, spurge, a genus of Euphorbiaceae.

Excentric: out of the center.

Exuding: L. exudare, to sweat out. Giving out liquid matter through pores or incisions.

Facies: L. facies, face, aspect, a controlling species of a formation.

False branch: an apparent branch arising in Scytonemataceae and Rivulariaceae by the out-growth or attachment of hormogones.

Family: a group of plants next below an order in rank, as Chroococcaceae.

Fastigiatus: L. fastigiatus, clustered.

Fertile: bearing reproductive or propagative organs or bodies.

Fibrous tissue: tissue in which the cells are greatly elongated and tapering.

Fibro-vascular bundles: the bundles of fibers and ducts which compose the skeleton system of plants.

Fibrovascular system: all the bundles which form the skeletal or supportive tissues of the plant.

Filament: L. filamentum, a thread or chain of cells.

Filicales: L. filix, fern.

Filicineae: L. filix, fern.

Fission: the process of cell increase by a gradual pinching in two of the cell.

Flexilis: L. flexilis, flexible, yielding.

Floret: diminutive of L. flos, floris, flower, one of the small flowers of a head, in the Composites.

Florideae: L. floridus, bright.

Flower: the reproductive axis and its parts among the Anthophytes.

Flower cluster: the group of flowers upon a stem or receptacle.

Formation: a definite area of the vegetative covering, composed of plants adapted to the same conditions.

Fraxinus: L. fraxinus, an ash-tree.

Frequence: the sum of the stations or localities in which a formation or a species occurs.

Fruit: the mature macrosporophyll with its seeds, often including the receptacle or some of the sterile sporophylls.

Fruit dot: a cluster of spores or sporangia, a sorus.

Fucus: L. seaweed.

Funaria: L. fune, rope.

Function: L. fungor, do, the work or working of an organ or part.

Fundamental system: the collection of tissues, chiefly parenchyma, which makes up the plant with the exception of the bundles and the epidermis.

Fungus: L. fungus, mushroom, the term applied to any chlorophyll-less plant of the first three branches.

Galium: Gr. dim. of γάλα, gala, milk.

Gametophyte: Gr. γαμέτης, gametes, spouse, φυτόν, phyton, plant, the structure which bears the archegones and antherids; the prothallium or sexual generation.

Gasteromycetales: Gr. γαστήρ, gaster, abdomen, μύκης, mykes, mushroom.

Geitonogamy: Gr. γείτων, geiton, neighbor, γάμος, gamos, marriage, the fertilization of one flower by the pollen of another flower of the same plant.

Gemmation: L. gemmatus, jewelled.

Generation: that which is generated or produced, such as the gametophyte or sporophyte.

Genus: a group of closely related species, as Gloeocapsa.

Geotropism: Gr. γαῖα, gaia, the earth, τρέπειν, trepein, to turn, a tendency to grow or incline toward the earth.

Germinate: L. germano, sprout, begin to grow, sprout.

Gesneriana: L. gesnerianus, of Gesner.

Gill: one of the flat, spore-bearing plates on the underside of the cap of mushrooms.

Globose: L. globosus, round, like a ball.

Gloeocapsa: Gr. γλοιός, gloios, glue, κάψα, kapsa, chest.

Gloeotrichia: Gr. γλοιός, gloios, glue, θρίξ, thrix, hair.

Glumales: L. gluma, husk.

Gracile: L. gracilis, graceful.

Graminis: L. gramen, grass.

Gymnospermae: Gr. γυμνός, gymnos, naked, σπέρμα, sperma, seed.

Gynoecium: Gr. γυνή, gyne, woman, οἰκίον, oikion, house, the macrosporophyll or pistil of a flower.

Habitat group: a collection of species growing in similar physical conditions and exhibiting similar adaptations.

Haematoxylin: Gr. αἷμα, haima, -ατος, atos, blood, ξύλον, xylon, wood, a blue stain obtained from the logwood (Haematoxylon campechianum).

Hair: a pushing-out of the epidermis into a hair-like cell, or many-celled structure.

Half-cell: one of the symmetrical halves of a desmid cell.

Hamata: L. hamatus, hooked.

Hapaxanthous: Gr. ἅπαξ, hapax, once, ἄνθος, anthos, flower, flowering but once, annual.

Head: a flower cluster in which the flowers are sessile on a short axis, as in the clover, or upon the receptacle, as in the dandelion.

Hemeranthous: Gr. ἡμέρα, hemera, day, ἄνθος, anthos, flower, opening during the daytime only.

Hepaticae: Gr. ἧπαρ, hepar, liver, through the L. hepaticus.

Heterocyst: Gr. ἕτερος, heteros, different, κύστις, kystis, cell, a clear yellow cell of Protophytes, of doubtful function.

Heterogamete: Gr. ἕτερος, heteros, different, γαμέτης, gametes, spouse, either of the two dissimilar reproductive cells, oosphere and antherozoid.

Hibiscus: Gr. ἱβίσκος, hibiskos, mallow, a genus of the Malvaceae.

Hilum: L. hilum, trifle, the central part of a starch grain.

Hirsutissima: L. hirsutissimus, very hairy.

Hirtum: L. hirtus, shaggy.

Histology: Gr. ἱστός, histos, web, λόγος, logos, word, the science of tissues.

Homogeneous: Gr. ὁμός, homos, same, γένος, genos, kind, similar throughout, uniform,

Hormogone: Gr. ὅρμος, hormos, chain, γονίον, gonion, offspring, a portion of the filament of a blue-green slime which breaks away and forms a new filament.

Hyacinthus: Gr. Ὑάκινθος, Hyacinthus, a genus of Liliaceae.

Hydrophyte: Gr. ὕδωρ, hydor, water, φυτόν, phyton, plant, a plant growing in a habitat with a large amount of available soil water.

Hygrometrica: Gr. ὑγρός, hygros, wet, μετρικός, metrikos, of measure, absorbing moisture.

Hylophyte: Gr. ὕλη, hyle, forest, φυτόν, phyton, plant, a wood-loving plant.

Hymenium: Gr. ὑμήν, hymen, membrane, the flat fruiting surface of an apothecium, consisting of asci and paraphyses.

Hymenomycetales: Gr. ὑμήν, hymen, membrane, μύκης, mykes, mushroom.

Hyphae: Gr. ὑφή, hyphe, web, the threads of a fungus.

Hysterium: Gr. ὑστέρα, hystera, cleft.

Hysterographium: Gr. ὑστέρα, hystera, cleft, γραφή, graphe, writing.

Impatiens: L. L. impatiens, impatient, a genus of Geraniaceae.

Inferales: L. inferus, below.

Infiltration: the process of penetration by liquids.

Intercellular space: a small space or canal between the cells in soft tissue.

Isodiametric: Gr. ἴσος, isos, equal, διάμετρος, diametros, diameter, of equal diameter.

Isogamete: Gr. ἴσος, isos, like, γαμέτης, gametes, spouse, one of two similar reproductive cells, a microzoogonidium.

Karyokinesis: Gr. κάρυον, karyon, nut, κίνησις, kinesis, moving, the rearrangement of the nuclear matter as a result of which two new nuclei are formed; nuclear division.

Lacustris: L. lacustris, pertaining to a lake.

Lamella: L. lamella, plate, one of the flat plates or gills on the under surface of the mushroom cap.

Lamellose: L. lamella, plate or layer, arranged in layers.

Lanceolata: L. lanceolatus, lance-shaped.

Latifolia: L. latus, wide, folium, leaf, broad-leaved.

Latticed: with open spaces, as in a lattice.

Layer: a group or stratum of plants of the same general height in a formation.

Leaf: a flat expanded organ borne laterally on the stem, a sterile sporophyll.

Lenticel: L. lenticula, lentil, the growth of cork tissue, stopping an old stoma.

Leucocrinum: Gr. λευκός, leukos, white, κρίνον, krinon, lily.

Leucoplast: Gr. λευκός, leukos, white, πλαστός, plastos, formed, a colorless body turning sugar into starch and developing chlorophyll in the light.

Lichen: Gr. λειχῆν, leichen, tree-moss, lichen, the term applied to cup fungi, black fungi, and thelephores parasitic upon algae.

Lignin: L. lignum, wood, the substance peculiar to woody and stony cell walls.

Liliaceae: L. lilium, lily.

Lithospermum: Gr. λίθος, lithos, stone, σπέρμα, sperma, seed.

Lobata: L. lobatus, lobed.

Lycoperdaceae: Gr. λύκος, lykos, wolf, πέρδον, perdon, puff.

Lycopersicum: Gr. λύκος, lykos, wolf, περσικόν, persikon, (Persian) peach, a genus of Solanaceae.

Lycopodium: Gr. λύκος, lykos, wolf, ποδίον, podion, little foot.

Macerate: L. macero, soften, to cause to separate, as the cells of a tissue.

Macrosporangium: Gr. μακρός, makros, large, σπόρα, spora, spore, ἀγγίον, angion, little vessel, a globose structure developed from the macrosporophyll and producing macrospores, an ovule.

Macrospore: Gr. μακρός, large, σπόρα, spora, spore, the large spore of ferns and flowering plants, producing the female prothallium upon germination.

Macrosporophyll: Gr. μακρός, makros, large, σπόρα, spora, spore, φύλλον, phyllon, leaf, the leaf upon which macrospores or macrosporangia are borne, a carpel.

Majus: L. major, greater.

Marchantia: from the botanist Marchand.

Marginatus: L. marginatus, margined.

Mays: Spanish maiz, Indian corn.

Medullary: L. medulla, marrow, pertaining to the pith, hence applied to the rays which extend from the pith through the wood.

Meristem: Gr. μεριστής, meristes, divider, primary tissue arising from an apical cell or group of cells, from which all other tissues are derived.

Mesophyll: Gr. μεσός, mesos, middle, φύλλον, phyllon, leaf, the parenchyma of the leaf, including sponge and palisade tissue.

Mesophyte: Gr. μεσός, mesos, middle, φυτόν, phyton, plant, a plant growing in a habitat characterised by medium quantity of available soil water.

Metabolism: Gr. μεταβολή, metabole, to change, the process by which living cells take up and convert into their own substance, the nutritive material brought them by the circulation, or by which they transform their protoplasm into simpler substances.

Methyl green: Gr. μετά, meta, belonging to, ὕλη, hyle, wood, a green stain belonging to the anilin series.

Micrampelis: Gr. μικρός, mikros, short, ἀμπελίς, ampelis, vine, a genus of Cucurbitaceae.

Micrometer: Gr. μικρός, mikros, small, μέτρον, metron, measure, a small scale placed in the eye-piece for measuring microscopical objects.

Microspora: Gr. μικρός, mikros, small, σπόρα, spora, spore.

Microsporangium: Gr. μικρός, mikros, small, σπόρα, spora, spore, ἀγγίον, angion, little vessel, a modification of part of the microsporophyll in which microspores or pollen grains are produced.

Microspore: Gr. μικρός, mikros, small, σπόρα, spora, spore, a small spore developed in a microsporangium or anther, and producing a male prothallium, a pollen grain.

Microsporophyll: Gr. μικρός, mikros, small, σπόρα, spora, spore, φύλλον, phyllon, leaf, a leaf which bears microspores or microsporangia, a stamen.

Microtome: Gr. μικρός, mikros, small, τομή, tome, a cutting, an instrument for cutting very thin sections.

Migration: L. migratio, change of abode, the movement of a species or group of species into new stations.

Milk tissue: a tissue traversed by ducts or tubes containing a milky substance.

Milk tube: a duct or tube secreting a resin of a milky character.

Monocotyledones: Gr. μόνος, monos, single, κοτυληδών, kotyledon, vessel.

Montanum: L. montanus, mountain.

Motile: L. motilis, possessing movement.

Mucedo: L. mucedo, mould.

Mucilage canal: a tube in which mucilage is formed.

Mucor: L. mucor, mould.

Multilocular: L. multus, many, loculus, little place, consisting of many cells, many-celled.

Muscineae: L. muscus, moss.

Mushroom, strictly, an edible fungus of the Agaraicaceae; more generally, any species of this family.

Mycelium: Gr. μύκης, mykes, fungus, the mass of vegetative filaments of a fungus.

Navicula: L. dim. of navis, ship.

Nematogeneae: Gr. νέμα, nema, thread, γένω, geno, bear.

Nitella: L. niteo, to shine.

Nitida: L. nitidus, shining.

Nodolusum: L. nodum, joint.

Normal: typical or standard.

Nose-piece: end-piece of a microscope carrying two or more objectives.

Nostoc: derivation doubtful.

Nothocalais: Gr. νόθος, nothos, spurious, κάλαις, kalais, topaz.

Nucleolus: L. nucleus, a deeply staining body surrounded by an areole, occurring singly, or several in the resting nucleus.

Nucleus: L. nux, nut, the central organ of the cell, usually globose in shape.

Nyctanthous: Gr. νύξ, nyx, night, ἄνθος, anthos, flower, flowering at night or upon cloudy days.

Objective: the lower set of lenses of the microscope, which bring the light rays to a focus.

Obliquus: L. obliquus, oblique.

Obstructive: checking or preventing the migration of plants.

Ocular: the upper set of lenses of the microscope, which magnify the image formed by the objective.

Oedogonium: Gr. οἶδος, oidos, swelling, γόνυ, gonu, joint.

-oideae: L. oideus, resembling.

Oogone: Gr. ὠόν, oon, egg, γονίον, gonion, offspring, the female organ of the Phycophytes which contains the oosphere or egg.

Oosphere: Gr. ὠόν, oon, egg, σφαῖρα, sphaira, ball, the egg-cell of the female organ, oogone, carpogone or archegone.

Oospore: Gr. ὠόν, oon, egg, σπόρα, spora, spore, the fertilized oosphene, a resting spore, the product of the fertilization of the oogone.

Open bundle: a collateral bundle in which the xylem and phloem are separated by cambium, and are capable of growth.

Order: a group of plants next below a class in rank, as Cystiphorae.

Orient: L. oriens, rising, hence east, to arrange a paraffin block so that it will be cut in the desired direction.

Orientalis: L. orientalis, pertaining to the East.

Oscillatoria: L. oscillare, oscillate.

Osmosis: Gr. ωσμός, osmos, an impulse, the mixing of two fluids by diffusion through an intervening porous membrane.

Ovule: L.L. ovulum, egg, the term applied to the macrosporangium of Anthophyta.

Palisade tissue: the soft tissue of the leaf composed of oblong, parallel cells.

Papilionaceae: L. papilio, butterfly.

Pappus: Gr. παππός, pappos, down (?), the bristles, hairs or scales to which the calyx is reduced in Compositae.

Paraphysis: Gr. παρά, para, alongside, φῦσα, physa, bellows, one of the sterile threads found with the asci or sporangia.

Parasite: Gr. παρά, para, alongside, σῖτος, sitos, wheat, food, a plant dependent upon another plant for its food.

Parenchyma: Gr. παρά, para, beside, ἐν, in, χυμός, chymos, juice, soft tissue making up the assimilative part of the plant.

Parmelia: Gr. παρμή, parme, small shield.

Patch: an irregular or indefinite group of plants belonging to one or more species.

Peculiar: found only in a certain region or district.

Pendula: L. pendulus, hanging.

Pepo: L. pepo, melon.

Perisporium: Gr. περὶ, peri, around, σποριον, sporion, little spore.

Perithecium: Gr. περὶ, peri, around, θήκη, theke, box, the spore fruit of the Pyrenomycetes.

Peronospora: Gr. περόνη, perone, point, σπόρα, spora, spore.

Petal: Gr. πέταλον, petalon, leaf, one of the inner row of sterile sporophylls, a part of the corolla.

Petiole: L. peticlus, the stalk of a leaf.

Peziza: L. pezica, sort of mushroom.

Phaeophyceae: Gr. φαιός, phaios, dark, φύκος, phykos, seaweed.

Phaeosporeae: Gr. φαιός, phaios, dark, σπόρα, spora, spore.

Phaseolus: L. phaselus, kidney bean, a genus of Leguminosae.

Phellogen: Gr. φελλός, phellos, cork, γενέω, geneo, bear, the meristematic tissue which produces cork.

Phloem: Gr. φλοιὸς, phloios, bark, the sieve or bast portion of the fibrovascular bundle.

Photo-synthesis: Gr. φωτος, photos, light, συνθεσις, sunthesis, to place or put together, the process of producing starch or sugar in the green plant, in the presence of light, by the absorption of carbon dioxide or water with the consequent evolution of oxygen.

Phycocyanin: Gr. φύκος, phykos, seaweed, κύανος, kyanos, dark blue, the blue-green pigment of the Protophytes.

Phycophyta: Gr. φύκος, phykos, seaweed, φυτόν, phyton, plant.

Physcia: Gr. φύσκη, physke, pudding.

Physcomitrium: Gr. φύσκη, physke, sausage, μιτρίον, mitrion, little cap.

Phytogeography: Gr. φυτόν, phyton, plant, γῆ, ge, earth, γραφή, graphe, writing, the study of the vegetative covering of the earth.

Pinus: L. pinus, pine, a genus of Pinaceae.

Pirus: L. pirus, pear-tree, a genus of Rosaceae.

Pistil: L. pistillum, pounding instrument, the macrosporophyll or female reproductive organ of the Anthophyte.

Pistillate: bearing macrosporophylls or pistils alone: as a pistillate flower.

Pisum: Gr. πισος, pisos, garden pea, a genus of Leguminosae.

Placental scale: a large outgrowth of the macrosporangium of the pines, constituting the larger bulk of the cone.

Plastid: Gr. πλαστός, plastos, formed, a definite bit of protoplasm capable of producing a pigment, and of increase by fission.

Pleiocyclic: Gr. πλεῖος, pleios, full, κύκλος, kyklos, circle, flowering year after year, perennial.

Pleurococcus: Gr. πλευρός, pleuros, side, κοκκός, kokkos, berry.

Poa: Gr. ποά, poa, grass.

Pod: a dry splitting fruit, a macrosporophyll containing several seeds or sporangia and splitting when dry.

Polemonium: Gr. πόλεμος, polemos, battle.

Pollen: L. pollen, mill-dust, the microspores of flowering plants.

Polyanthous: Gr. πολύς, polys, many, ἄνθος, anthos, flower, bearing many flowers.

Polymorpha: Gr. πολύς, polys, many, μορφή, morphe, form.

Polypodium: Gr. πολύς, polys, many, ποδίον, podion, little foot.

Polysiphonia: Gr. πολύς, polys, many, σίφων, siphon, tube.

Polyspermous: Gr. πολύς, polys, many, σπέρμα, sperma, seed, bearing many-seeded fruits.

Poophyte: Gr. ποά, poa, grass, φυτόν, phyton, plant, a plant growing in grassland.

Populus: L. populus, poplar, a genus of Salicaceae.

Pratensis: L. pratensis, of a meadow.

Prevernal: L. prae, before, vernalis, spring, appearing in earliest spring.

Primitive: L. primitivus, early, first, earliest, simplest.

Principal species: those species of a formation next to facies in abundance and importance.

Propagation; asexual increase of cells, as by fission, budding, nuclear division, etc.

Prothallium: Gr. πρό, pro, before, θαλλίον, thallion, a young shoot, the plant which bears antherids and archegones, both in Anthophytes and Pteridophytes.

Protococcus: Gr. πρῶτος, protos, first, κόκκος, kokkos, berry.

Protonema: Gr. πρῶτος, protos, first, νέμα, nema, thread, the first filamentous stage of the moss plant.

Protophyta: Gr. πρῶτος, protos, first, φυτόν, phyton, plant.

Protoplasm: Gr. πρῶτος, protos, first, πλάσμα, plasma, form, the semi-fluid substance which makes up the basis of active cells.

Province: one of the main divisions of the vegetative covering.

Prunus: L. prunus, plum tree.

Pteridophyta: Gr. πτερίς, pteris, fern, φυτόν, phyton, plant.

Pteris: Gr. πτερίς, pteris, fern.

Puccinia: from an Italian botanist, Puccini.

Puff-ball: the powdery spore-fruit of most Gastromycetes.

Pulsatilla: L. pulsatus, shaken, blown about.

Pyrenoid: Gr. πυρήν, pyren, stone, εἶδος, eidos, form, a bit of protoplasm usually associated with the chloroplast in algae, used for storing starch.

Pyrenomycetales: Gr. πυρήν, pyren, stone, μύκης, mykes, mushroom.

Radial: grouped like the radii of a circle.

Ranales: L. rana, frog.

Ranunculus: L. ranunculus, little frog.

Ray: the outer radiate portion of a composite, consisting of strap-shaped florets.

Ray floret: the strap-shaped flower of the margin of a head, as in the sunflower.

Receptacle: L. receptaculum, receptacle, the portion of the axis bearing the sporophylls.

Rigidity: L. rigiditas, stiffness, the quality of being rigid, of resisting change of form.

Region: a division of the province.

Reproduction: the fusion of two sexual cells out of which arises the new plant.

Resin canal: a tube in which resin is found.

Resting spore: a spore protected by a thick wall designed to carry a plant through unfavorable conditions.

Reticulate: L. reticulum, net, resembling a network, netted.

Rhizoid: Gr. ῥίζα, rhiza, root, εἶδος, eidos, form, one of the thread-like hairs which serve the purpose of roots among the Bryophytes and Pteridophytes.

Rhodomelaceae: Gr. ῥόδον, rhodon, rose, μῆλον, melon, apple.

Rhodophyceae: Gr. ῥόδον, rhodon, rose, φῦκος, phykos, seaweed.

Ribes: Arabic, ribes, gooseberry.

Rivularia: L. rivulus, rill.

Rosa: L. rosa, rose.

Rubiales: L. rubia, madder.

Ruderal: L. ruderalis, of rubbish, pertaining to weeds.

Rupestris: L. rupestris, of a shore or bank.

Rust: the common name of the species of Uredineae.

Saccharomyces: Gr. σάκχαρον, sakcharon, sugar, μύκης, mykes, mushroom.

Safranin: Fr. safran, fr. Ar. zafaran, yellow, a red stain belonging to the coal-tar colors.

Sagittaria: L. sagittarius, archer, a genus of Alismaceae.

Salicis: L. salix, salicis, willow.

Sambucus: Gr. σαμβύκη, sambyke, a musical instrument, a genus of Caprifoliaceae.

Saprophyte: Gr. σαπρός, sapros, putrid, φυτόν, phyton, plant, a plant growing upon organic matter, but not on living organisms.

Sativum: L. satīvus, sown, cultivated.

Saxifragaceae: L. saxum, rock, frango, break.

Scale: a small, leaf-like appendage found on buds, stems, etc.

Scenedesmus: Gr. σκηνή, skene, tent, δεσμός, desmos, band.

Schizophyceae: Gr. σχίδξω, skidzo, split, φῦκος, phykos, seaweed.

Scirpus: L. scirpus, rush, a genus of Cyperaceae.

Sclerenchyma: Gr. σκληρός, skleros, hard, ἐν, en, in, χυμός, chymos, juice, stony tissue, in which the cell wall is greatly thickened and hardened by lignin; a tissue in which the walls are lignified.

Scutellata: L. scutellatus, disk-shaped.

Scytonema: Gr. σκύτος, skytos, leather, νέμα, nema, thread.

Secondary species: one of the less important species of a formation.

Secretory passage: a canal or tube in which various gums, resins, etc., are stored.

Segment: L. seco, cut, section, joint.

Selaginella: L. dim. of selago, name of a plant.

Senecio: L. senex, an old man.

Sepal: L. separo, separate, one of the outer row of sterile sporophylls: a part of the calyx.

Sepultaria: L. sepultum, buried.

Serotinal: L. serus, late, autumnal.

Sheath: the mucilaginous covering of the cell or filament of many Protophytes.

Shield: the sporophyll of the horse-tails.

Sieve plate: one of the perforated partitions of the sieve tubes, through which the protoplasm is connected.

Sieve tissue: a component tissue of the fibrovascular bundles, consisting of sieve tubes and companion cells.

Sieve tube: a row of elongated cells, separated by perforated end partitions or sieve plates.

Siphoneae: Gr. σίφων, siphon, tube.

Soft tissue: tissue composed of thin-walled, cellulose cells, charged with the assimilative function.

Solanum: L. L. solanum, nightshade, a genus of Solanaceae.

Sorus: Gr. σορός, soros, vessel, a sac containing spores; or a definite portion of tissue where spores or sporangia are found.

Species: L. species, aspect, a group of individuals differing from each other only in insignificant characters.

Spherical: Gr. σφαῖρα, spnaira, ball, round, as a ball.

Spikelet: the flower cluster of the sedges and grasses, a small spike.

Spirillum: Gr. σπειρύλλιον, speiryllion, little spiral.

Spirogyra: Gr. σπεῖρα, speira, spiral, γυρός, gyros, ring.

Splendens: L. splendens, showy.

Sponge tissue: the loose, soft tissue of the leaf.

Sporangium: Gr. σπόρα, spora, spore, ἀγγίον, angion, little vessel.

Spore: Gr. σπόρα, spora, seed, a propagative or reproductive body of the cryptogams.

Spore fruit: the fruiting body of the Carpophyta, perithecium, apothecium, cystocarp, or peridium.

Spore sac: a membranous sack containing spores, an ascus.

Sporophyll: Gr. σπόρα, spora, spore, φύλλον, phyllon, leaf, a flat expansion of tissue, with or without organs of multiplications.

Sporophyte: Gr. σπόρα, spora, spore, φυτόν, phyton, plant: the plant produced by the fertilization of the archegone, in the mosses the capsule, in the ferns the frond, and in the Anthophytes, the whole visible plant.

Stamen: L. stamen, thread, the microsporophyll, the organ which bears the microspores or pollen.

Staminate: bearing microsporophylls or stamens alone, as a staminate flower.

Stellate: L. stellatus, starry, star-shaped.

Sterile: lacking both reproductive and propagative bodies.

Stipple: D. stip, dot, draw or shade by means of dots.

Stomata: pl. of stoma.

Stoma, pl. stomata: Gr. στόμα, stoma, mouth, the opening through the epidermis provided with guard cells.

Stone-cell: an isodiametric cell having a thick lignified wall.

Stone fibre; an elongated, thickened cell, with lignified wall.

Stonewort: the common name for the Characeae, derived from the lime incrustations of the stem and leaves.

Subclass: the name of the group next below the class in rank.

Suberin: L. suber, the cork-oak, the substance peculiar to cork.

Suborder: the name of the group next below the order in rank.

Subtilis: L. subtilis, fine, delicate.

Summer spore: a conidium or uredospore of the rusts, capable of immediate germination.

Symmetry: Gr. σύν, syn, with, μέτρον, metron, measure, harmony of arrangement.

Syriaca: L. syriacus, of Syria.

Taraxacum: Gr. ταραξις, taraxis, disorder.

Tenuis: L. tenuis, thin.

Tetraspore: Gr. τὲτρα, tetra, four, σπόρα, spora, spore, the asexual spore of the red seaweeds, usually produced in fours.

Thalamiflorales: Gr. θάλαμος, thalamos, chamber, L. flos, flower.

Thallus. Gr. θάλος, thalos, shoot, the plant body or plant mass.

Thermostat: Gr. θερμή, therme, heat, ἵστημι, histemi, stand, an instrument to regulate automatically the flame of a burner.

Thick-angled tissue: tissue composed of elongated cells, thickened at the angles.

Tissue: a definite group of similar cells with a particular function.

Trachea: L. L. trachia, a vessel.

Tracheary: pertaining to a trachea.

Tracheids: L. L. trachea, vessel, an elongated fibre-like cell with closed ends and usually bordered pits or spiral markings.

Trama: L. trama, woof, the central tissue, consisting of small filaments, of the gills of mushrooms.

Transverse: at right angles to the long diameter.

Triticum: L. triticum, wheat, a genus of Graminaceae.

Tropaeolum: Gr. τρόπαιον, tropaion, trophy, a genus of Geraniaceae.

Tuber: Latin name for the truffle.

Tuberosum: L. tuberosus, bearing a tuber.

Tulipa: Fr. tulipe from Per. dulband, turban.

Turgidity: L. turgidus, swollen, a condition of being swollen or unnaturally distended.

Type: the form or character of an organism, the organism itself when it represents a larger group.

Typical: representative, characteristic.

Ulothrix: Gr. οὖλος, oulos, fine, φρίξ, thrix, hair.

Uncinula: L. little hook.

Undula: L. dim. of unda, wave.

Unilocular: L. unus, one, loculus, little place, one-celled.

Uredo: L. uredo, a blasting.

Ustilago: L. ustus, burnt.

Vacuole: L. vacuum, space, a bubble of water in the protoplasm.

Vaucheria: from Vaucher a French botanist.

Vegetation: the plant covering of the globe.

Vegetation form: a structural type, considered chiefly with respect to duration.

Vegetative body: the part of the plant concerned in the process of nutrition.

Vegetative cell: a cell which carries on any physiological process except that of reproduction.

Vegetative covering: the sum of plant formations.

Vernal: L. vernalis, spring.

Vessel: a long tube composed of a row of cells in which the end walls have dissolved.

Viridis: L. viridis, green.

Vulgaris: L. vulgaris, common.

Whorl: three or more leaves in a circle at the same level.

Winter spore: the resting spore or teleutospore of the rusts, designed to carry the plant through the winter.

Wood fibre: a short, rather thin-walled, lignified fibre, making up the greater part of woody tissue.

Xenogamy: Gr. ξένος, xenos, stranger, γάμος, gamos, marriage, fertilization between the flowers of two different individuals, stranger cross-fertilization.

Xerophyte: Gr. ξερός, xeros, dry, φυτόν, phyton, plant, a plant growing in a habitat where there is little available soil water.

Xylem: Gr. ξύλον, zylon, wood, the wood or tracheary portion of the fibrovascular bundle.

Zea: Gr. ζειά, zeia, grain, a genus of Graminaceae.

Zebrina: African zebra, striped.

Zone: Gr. ζώνη, zone, belt, girdle, a strip or belt-like area of vegetation.

Zoogonid: Gr. ζῶον, zoon, animal, γονίδιον, gonidion, young, a motile spore provided with cilia, found in Phycophytes.

Zoosporangium: Gr. ζῶον, zoon, animal, σπόρα, spora, spore, ἀγγίον, angion, vessel, a cell or modified branch in which zoospores or zoongonidia are formed.

Zoospore: Gr. ζῶον, zoon, animal, σπόρα, spora, spore, a motile propagative or reproductive body, microspore and macrospore.

Zygnema: Gr. ζυγόν, zygon, yoke, νέμα, nema, thread.

Zygomorphic: Gr. ζυγόν, zygon, yoke, μορφή, morphe, form, bilaterally symmetrical, as the flower of a mint.

Zygote: Gr. ζυγωτός, zygotos, yoked, the resting spore formed by two isogametes, as in Spirogyra and Ascophora.